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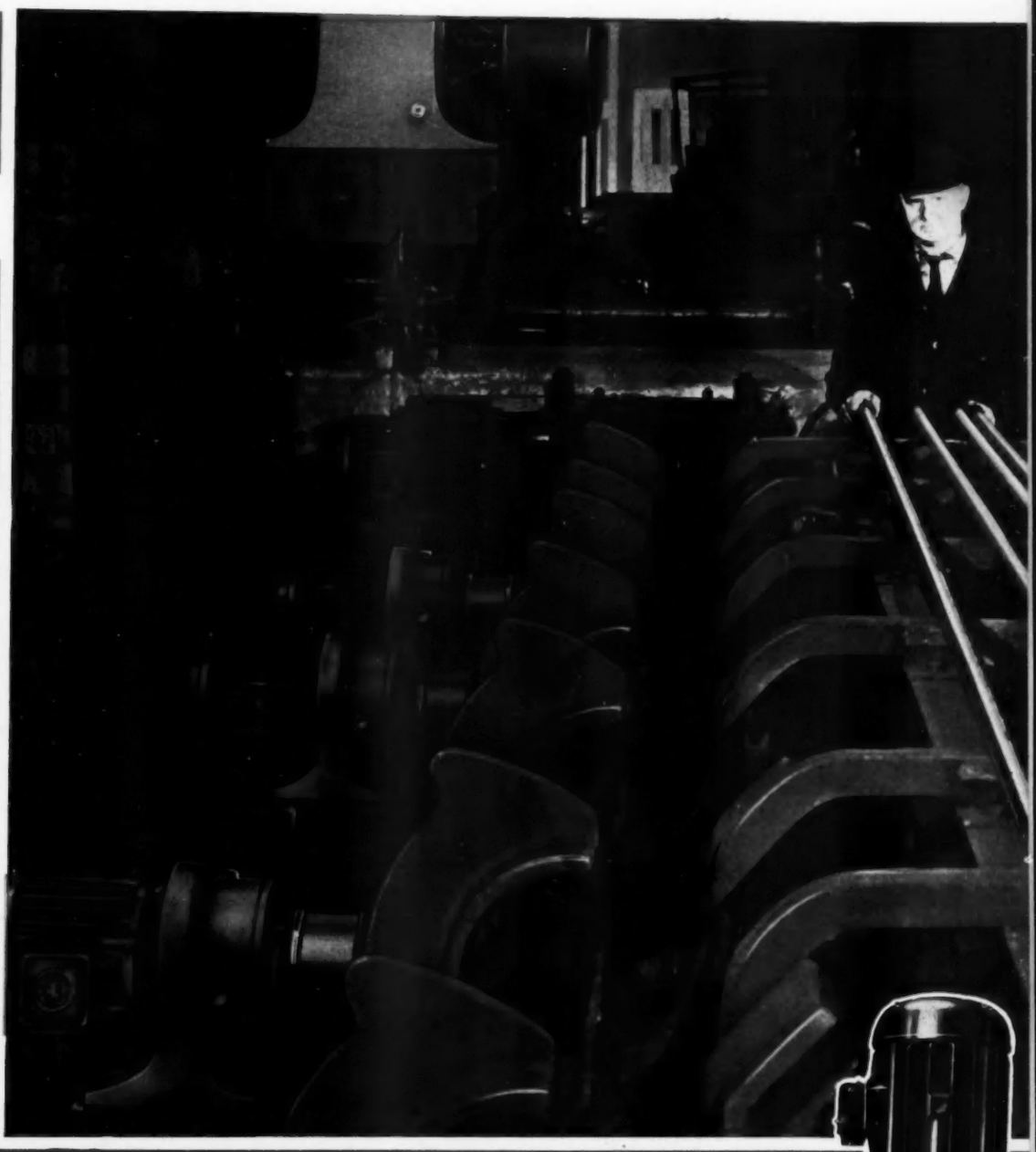

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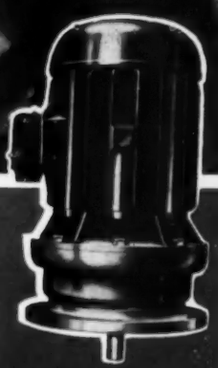

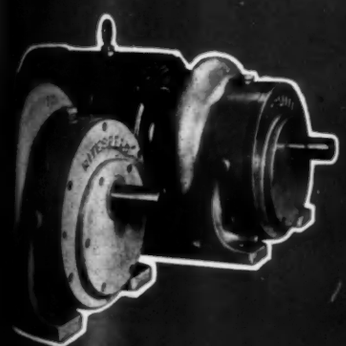

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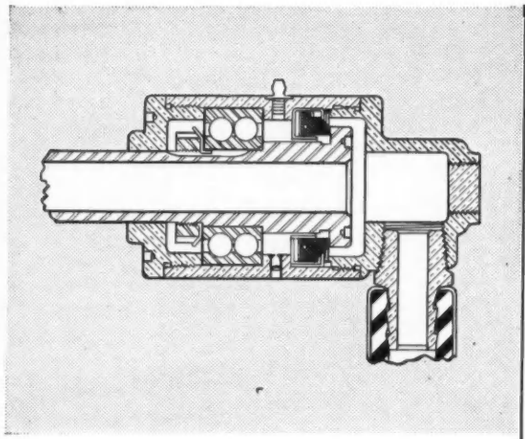

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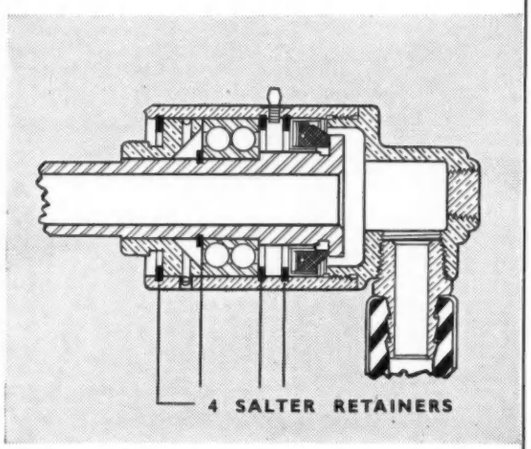

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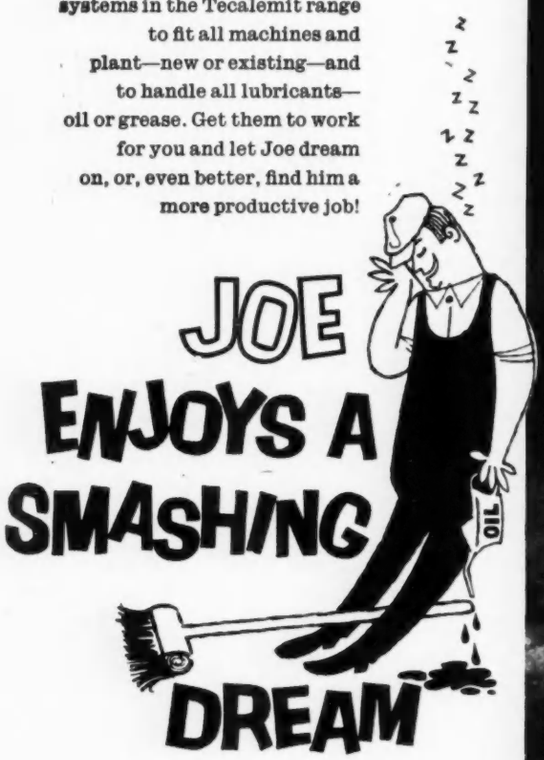

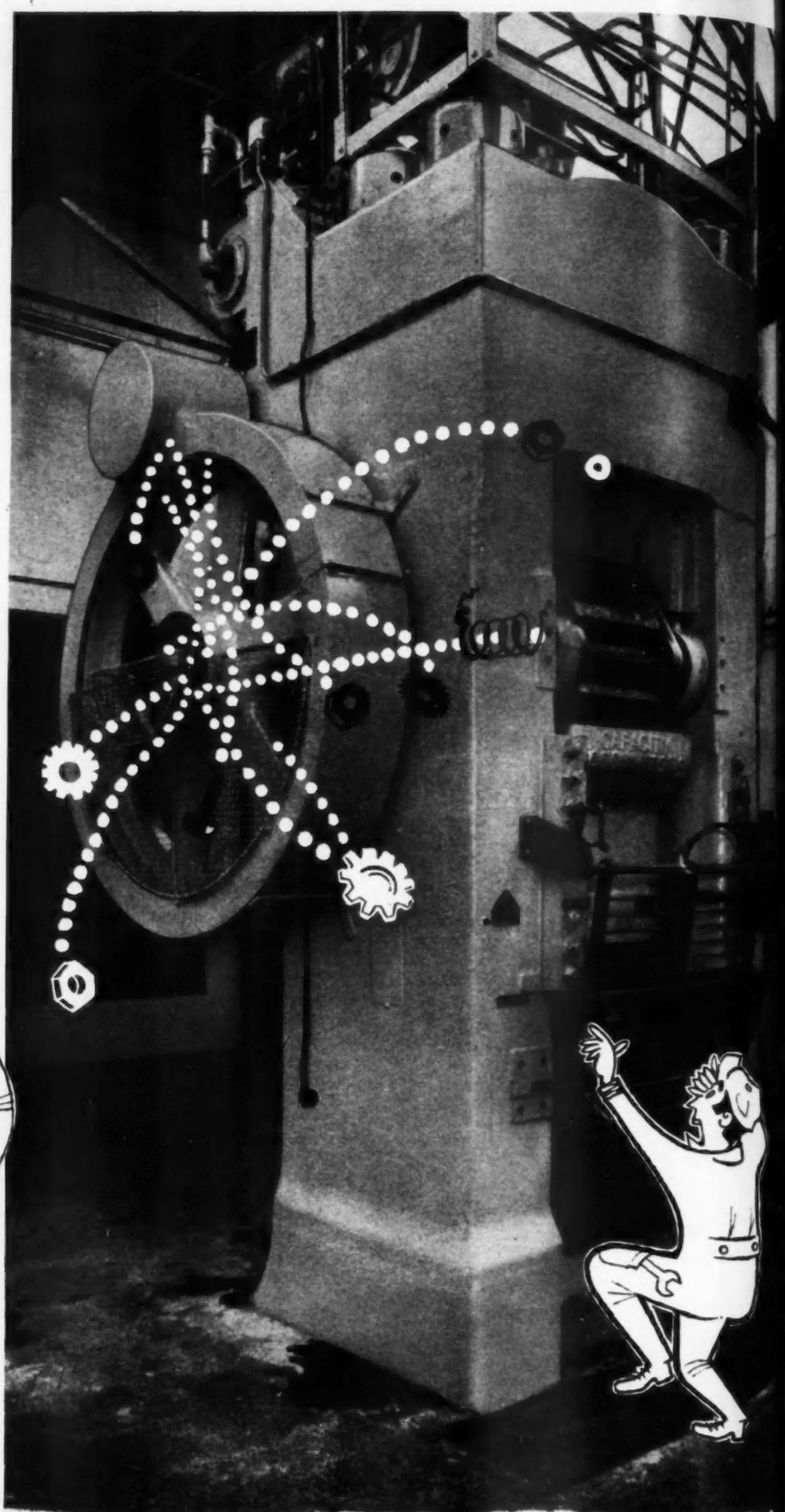

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THE ENGINEER

No. 5522 NOVEMBER 24, 1961 Vol. 212

PAUSE OR NO PAUSE

In July of this year the Chancellor of the Exchequer, in what has since become familiarly known as his "little budget", stressed "that increases in incomes must follow and not precede or outstrip increases in national productivity". We commented at the time that after years of a tacitly accepted "free-for-all" in wages claims it would not be easy to persuade the trade unions to accept a "pause", and that it would be helpful if the unions could be convinced that the "pause", voluntary or compulsory, would apply equally to all incomes, including those from dividends and, particularly, from speculative sources. In short, we added, the Government might have to be tough but it would have a better chance of succeeding if the toughness was seen to be applied equitably.

Since the advent of the pause, the wage-claim "free-for-all" has simmered gently under the watchful eye of the Trades Union Congress. But last week the T.U.C.'s cook decided that the fire under the "wage-pot" needed a little poke. This took the form of a letter to the Chancellor in which the T.U.C. pointed out that during the first eight months of this year hourly wage rates rose by two per cent, compared with a three per cent rise in productivity, while in the manufacturing industry they rose about one per cent compared with a five per cent productivity increase. As well as poking the fire, the T.U.C. introduced a little draught by pointing out that in the same period dividends increased by about fourteen per cent. The letter calls upon the Chancellor to further reduce the Bank rate, and to forthwith take steps to prevent a further weakening of Britain's economic position, these steps to include, as a minimum, a cut in the surcharge on indirect taxes and the termination of the wages pause.

But perhaps the severest threat to the Chancellor's pay-pause policy is the news last week that one of the nationalised industries had agreed that a wage increase should be operative from January 28, instead of April 1. The Electricity Council announced that all manual workers would receive an increase in the grade rate of 2d. an hour with effect from the first full pay period following January 28, 1962. This posed the Chancellor a pretty problem. For this is the season of wage claims and because of the settlement in the electricity supply industry, other employers will no doubt be pressed hard to agree that increases which are granted should become operative early in the new year. Among the wage claims at present pending is one for some 3,000,000 engineering workers who are asking for a "substantial rise" and a reduction of hours, and a similar claim for shipbuilding workers. The mineworkers have asked for an increase of £1 a week and a reduction of hours, and some of the railway unions have claims pending.

Supporting the Chancellor in the House last Tuesday, Mr. Macmillan declared that the award did not have the blessing of the Government, and that the economic situation demanded that the measures he outlined in July be continued. But we cannot help feeling that the Chancellor will find it almost impossible to continue his "pause" in the face of the unions' cry that what is good for the electrical goose is good for their own particular ganders. As we go to press we learn that the General Council of the T.U.C. is to meet on Thursday, November 23, when it will decide if it is to inform the Chancellor of its willingness to take part in the National Economic Development Council. If its decision is to join, it will be interesting to note what effect this has upon the pay pause.

MACHINE TOOLS AND THE COMMON MARKET

The machine tool industry of this country has long been the butt of criticism. We ourselves have done some of the criticising. It is still possible to criticise it. Notably the industry has failed to develop certain of the more specialised tools required for modern high precision mass production. This country, which once led the world in the development of machine tools, now tends to trail behind others. The industry has tended to concentrate on the making of, admittedly excellent, general purpose machines, leaving many of the more specialised tools to be imported. But, whereas a few years ago it seemed to us very desirable that the industry should be reminded of its shortcomings at every suitable opportunity, we no longer think so now. Instead we think it needs encouragement. No doubt much complacency remains. But there have emerged from within the industry those who can and do, from their specialised knowledge of the industry's problems, criticise if far more effectively from within than can any outsider. Over the last two or three years things have really started to move. In reply to the Toast of the Association at the annual dinner of the Machine Tool Trades Association on Thursday of last week Mr. J. C. Snow, the President, remarked, "During this last year or so I have noticed a new keenness and awareness amongst members of our committees and council of the problems which our industry has to face, and I have been most impressed by the way these problems are being tackled. It is not long ago that we realised the necessity of providing advanced educational facilities for our machine tool designers." He was referring of course to the arrangement made with the Manchester College of Science and Technology to provide a two-year course for ten scholars annually in machine tool design and technology. For years there have been complaints in the industry about the difficulty of obtaining good designers. Even now it must certainly seem to an outsider that a mere ten scholars a year is not going to put the matter right in a hurry. But, as the President remarked "with your support this could grow into something much larger which could provide our industry with the highly qualified designers it must have." Another recent event is the creation of the first Chair in this country in Machine Tool Technology at Manchester University. Two conferences, one held rather more than a year ago at Birmingham, the other quite recently at Manchester, both revealed a rather startling gap between those with academic knowledge of machine tools and even those with practical knowledge of building them. Even at the second of those conferences the two sides, the theoreticians and the practical people,

still barely understood one another! An increase within the manufacturing industry of people who have had academic training should go some way to bring the two sides into better contact. Each has something to contribute to design. Furthermore the setting up of a Machine Tool Research Association should help to do the same.

The President made his speech in the context of an opening speech by Mr. Watkinson, Minister of Defence, which was largely concerned with the negotiations now going on towards the entry of this country into the European Economic Community. Already, as a consequence of the creation of the E.E.C., this country's machine tool exports to Western Europe have gone sharply up. They might go up still faster were Britain within the Common Market. In fact an opportunity is opening before the machine tool industry, as, indeed, before other industries too. But industry will need to be efficient if it is to compete. On that matter the President was able to reveal some statistics arising out of a survey, the full report upon which will not be published until the very end of the year, into the age of machine tools in British industry. Some 65 per cent, it seems, are more than ten years old and some 28 per cent are over twenty years old. There is even one remarkable veteran, still in use, over 120 years old! In a back-handed way those figures may be regarded as encouraging, for the British engineering industry manages to compete pretty effectively on the Continent despite the age of its machine tool population. Obviously its productivity could be sumstantially raised and its prices be made still more competitive were it to be equipped with more modern tools.

RAILWAY ACCIDENTS IN 1960

Total casualties on the railways of this country in 1960 (including accidents to trespassers and suicides) were 487 killed and 22,473 injured. Those involved in normal railway operations were 226 killed and 22,378 injured, comparing with 231 and 22,877 respectively in 1959. In his annual report,* Brigadier C. A. Langley, Chief Inspecting Officer of Railways, comments that the fatalities in 1960 were less than half those in 1946. The lower number of deaths compared with 1959 was largely due to a reduction from 191 to 176 in those caused by movement accidents. Train accidents, on the other hand, accounted for thirty fatalities compared with sixteen in 1959, but only six of these were passengers, and occurred in two accidents (five in the derailment and collision at Settle, and one in a buffer stop collision at Bradford). The number of passenger train collisions and derailments (160) was the lowest since the war, but collisions and derailments of freight trains rose sharply to 255. Several serious derailments during the year were caused by the running of short-wheelbase vehicles at marginal speeds. New motive power, and the narrowing of the speed gap between different classes of trains which is implicit in the modernisation plan, combine to make this problem pressing.

Brigadier Langley comments on an increase in accidents due to human failings, which although below the 1957 peak were 37 per cent more in 1960 than in 1946. The upward trend, fortunately, did not apply to accidents caused by drivers passing signals at danger and signalmen's errors, the former totalling forty-two compared with forty-four in 1959, and the latter remaining steady at fifty-one. The problem of drivers passing signals at danger is still being investigated by the Medical Research Council, which undertook this task at the request of the British Transport Commission. Typical cases notified to the Council's committee on this subject were the overrunning of a colour-light signal by an experienced driver in daylight and good visibility, and failure to observe a speed restriction; while a member of the committee attended the inquiry into a collision caused by a driver overrunning a signal on a clear night and colliding with a goods train ahead, the lights of which he failed to observe for over twenty seconds.

Errors by signalmen are a reminder of loopholes that exist when regulations are disregarded, or equipment is tampered with either to cover a mistake or because its indications are disbelieved or misinterpreted. A case is quoted of electric locking being released to accept a passenger train into a section occupied by a light engine which had been forgotten in thick fog. Elsewhere the installations themselves needed modification, such as the track diagram from which a signalman wrongly deduced that when a particular track circuit was clear, a train backing into a siding must necessarily have cleared the fouling point with the main line. In another mishap a porter instructed to work electric points manually for an emergency movement inserted the crank handle into the wrong machine in the dark, and diverted an empty stock train into an occupied track. Although his action put the relevant signal to danger, the approaching train had already passed it. Against occurrences such as these an automatic warning system is no final protection, but it may be hoped that the somewhat disappointing progress in a.w.s. installation to which Brigadier Langley refers is explained by the priority being given to new signalling installations which reduce still further the risks of misuse or negligence.

* Report to the Minister of Transport on the accidents which occurred on the Railways of Great Britain during the year 1960. H.M.S.O. Price 6s. 6d.

The Engineer—100 Years Ago (NOVEMBER 22, 1861)

THE "OCTAVIA" STEAMSHIP

"One of the most important screw trials which have taken place for some time in the navy took place at Portsmouth on Wednesday . . . ." This was the trial of the screw ship *Octavia*, built as a sailing frigate but converted to screw propulsion before commissioning. Some hull alterations were involved, but the main interest was in the fact that the ship was the first to be completed of three vessels with machinery designed to meet special requirements. Each ship was engined by a different manufacturer, the ships being the *Constance*, *Arethusa* and *Octavia*, and the engine builders Penn and Son, Randolph and Elder, and Maudslay Sons and Field, respectively. Each of the engine builders competed to produce engines, without limit to cost of manufacture or design, which should be economical in working, and of 500 nominal h.p. *Octavia's* engines were designed and their principle patented by Mr. Sells, chief draughtsman for Maudslay Sons and Field, and had three cylinders 66in diameter by 3ft 6in stroke, steam jacketed, and exhausting to a surface condenser. No further details are given of the engine but, working with superheated steam from "tubular" boilers it was evidently satisfactory, for it had been "proved" that coal consumption would not exceed half that used in ordinary instances.

Smooth operation of the engine in particular excited comment, and the trial was considered to be "most satisfactory." The ship made a number of runs at both half and full power, the vacuum in the condenser being held at 28½ lb. Over six full-power runs the mean speed was 12·255 knots and over four half-power runs it was as nearly as possible 10 knots. Another feature which was outstanding was the coolness of the engine and boiler rooms; at full power the engine room temperature was 58 deg., and that of the boiler room from 65 to 80 deg., according to the position.

Articulated Tracked Vehicles

By R. M. OGORKIEWICZ, M.Sc.(Eng.), A.M.I.Mech.E.

There has been a significant revival of interest in articulated tracked vehicles and during the past few years several have been built in the United States and Canada. The following article reviews their development and discusses the principal features of this interesting but little known type of vehicle.

DURING the fifty-odd years of their development, all but a few tracked vehicles have been built with two laterally rigid tracks. In consequence, they have been steered by creating a difference between the thrust generated by each track at the ground and thereby obtaining a turning moment which slews the tracks and turns the vehicle. Mechanisms devised for this purpose have been described in several articles[1, 2, 3, 4] and they have undoubtedly reached a high degree of refinement. But, in essence, steering by track slewing remains rather crude because of the way in which tracks have to be skidded over the ground, and it continues to impose serious limitations on the design and performance of tracked vehicles.

One major consequence of laterally rigid tracks and the associated skid-steering methods is that they confine the configuration of tracked vehicles within relatively narrow limits of the ratio of length to width, or, more precisely, of the ratio of the length of track in contact with the ground to the distance between the centre lines of the tracks. For serviceable vehicles this ratio must lie within the narrow range of 1·0 :1 to about 1·8 :1, because of the magnitude of the resistance to track slewing in relation to the maximum longitudinal thrust which a track can generate. As a result, tracked vehicles can not assume a longer and narrower form, which would be more advantageous for cross-country movement,[5] and the larger models are condemned to higher ground contact pressures than those possible with small vehicles, because weight increases as the cube of the linear dimension whereas ground contact area increases only as the square. Moreover, with the existing vehicles, when the soil under the track is stressed close to failure, the slewing moment necessary for steering can only be obtained by reducing the thrust of one track, since it is not possible to increase that of the other. Thus, steering is accompanied by a reduction in the total forward thrust and in soft soil may lead to complete immobilisation of the vehicle, as described in an earlier article.[6]

To overcome the shortcomings of laterally rigid tracks and skid-steering, a few attempts have been made to produce steering by track setting, but the difficulties associated with the laterally flexible tracks which are necessary and the complication of the track setting mechanisms have worked against the adoption of this method. It is interesting to note that these developments may be traced as far back as 1897, when the U.S. Patent No. 12,447 was taken out for J. A. Justice and P. Johnson, of Macey, Arkansas.[7] Curved track steering was also devised, apparently independently, in Australia by L. E. de Mole and embodied in the tracked armoured vehicle design which he unsuccessfully submitted to the War Office in 1912.[8] Yet another apparently independent attempt was made in this country in 1921 by Lt.-Colonel P. Johnson with his Light Infantry Tank. This amphibious vehicle was capable of speeds of up to 30 m.p.h. and thus represented a startling advance on the first generation of tanks built during the 1914–18 war but its laterally flexible " snake tracks " with lubricated spherical joints proved troublesome.[9] What is more, its development was not allowed to proceed very far as it was abandoned, together with Colonel Johnson's other designs, when the first Tank Design Department was closed down in 1923, in one of the government's periodic economy campaigns.

No further attempt to employ curved track steering appears to have been made until the 'thirties. In 1934, N. Straussler designed in this country a light turretless armoured vehicle which attempted to exploit the lateral flexibility of a conventional dry-pin track to provide a limited degree of steering by track setting ; the track was bowed by having the two inside road wheels, out of the four on each side, mounted on vertically hinged arms. The vehicle was built in 1935, by the Manfred Weiss Company, in Hungary, where a second, turreted armoured vehicle with a similar track assembly was subsequently made, but Straussler himself abandoned the provision for track setting almost immediately after the construction of the first vehicle and his later design embodied laterally rigid tracks each driven by a separate engine.

At about the same time, Vickers-Armstrongs, Ltd., also adopted a limited degree of track setting on the Bren Gun Carrier, this being accomplished by lateral displacement of one bogie on each side. In 1936, this was followed by the design of a light tank to the A.17 specification in which Vickers-Armstrongs incorporated a complete system of track setting by pivoting all four road wheels on each side of the vehicle. This vehicle, successively designated the Mark VII Light Tank and the " Tetrarch," saw limited service during the 1939–45 war[10] and, together with its later war-time derivatives, the " Harry Hopkins " airborne light tank and the " Alecto " self-propelled gun, still represents the most successful example of curved track steering.

To illustrate the performance of this type of vehicle, the " Alecto," which weighed 17,600 lb and was about 13ft 6in long overall without the gun, had a turning radius of 49ft using track curving alone. This was accomplished with a conventional type of track, laterally flexible to the extent permitted by the clearances between the track pins and the holes in the track links. The reduction of power losses by curved track steering was reflected in the good overall fuel economy of the vehicle but for tight turns it still had to use skid-steering and the additional complication of the track setting mechanism has not been considered justifiable in more recent designs.

Instead, there has been a revival of interest in articulated vehicles, whose manner of steering may be regarded as an approximation to curved track steering and which can dispense with skid-steering mechanisms altogether. Thus, while curved track steering involves bowing the whole length of the track in contact with the ground, the turning of articulated vehicles involves, in essence, disposing two or more laterally rigid tracks so that their centre lines are at an angle to each other and thereby approximating to curving of laterally flexible tracks. In general, articulated vehicles have been built with two units, each unit having two tracks like a conventional tracked vehicle, but a " bellyless " type with only one track for each unit is also feasible and one of the latest experiments involves three units, each having two tracks.

The idea of steering tracked vehicles by articulation appears to have originated later than curved track steering but the development of this type of vehicle began earlier. The first articulated tracked vehicle was designed in this country by B. J. Diplock

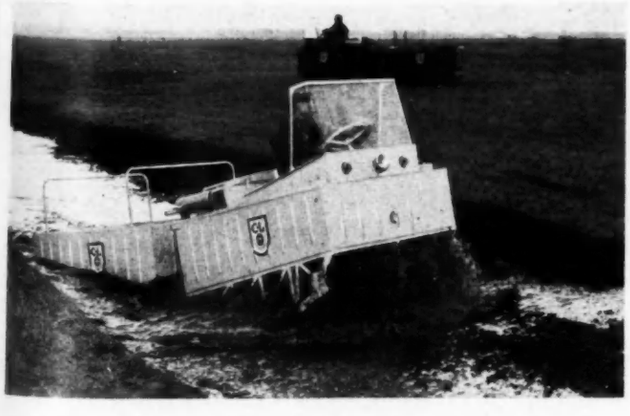

Fig. 1—Canadair CL-61 " Rats " light-weight articulated tractors

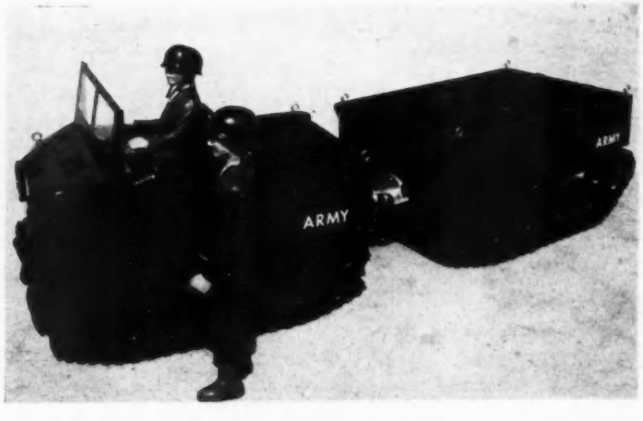

Fig. 2—Scale model of the recently announced ¼-ton high mobility carrier

around 1912 and was exhibited at the 1913 Commercial Motor Vehicle Exhibition at Olympia, in London. It was fully described on these pages at the time[11] and additional information on this and Diplock's other designs was subsequently given in the series of anonymous articles on the evolution of tracked vehicles published in THE ENGINEER in 1917,[12] which are worth mentioning since recent writers on the subject are obviously hazy about the early developments.

Diplock's original vehicle consisted of two units, each having two tracks, but only the front unit was powered. The two units were hinged by means of a joint with a pivot and guide, which allowed the two to roll relative to each other, and steering was accomplished by turning the rear unit relative to the front, or, to quote from page 99 of the July 25, 1913, issue, " by using this vehicle after the fashion of a rudder." The actual steering mechanism consisted of a worm mounted horizontally in the front unit and operated by the driver and a mating worm wheel sector on the rear unit. How it performed does not appear to have been recorded but Diplock's idea of an articulated tracked vehicle was taken up in 1915 by Colonel R. E. Crompton, who was engaged to design the first tracked " landships " and who proposed that they should be articulated. To explore this possibility a series of tests was carried out in July 1915 with two agricultural tracked tractors coupled together but this combination proved impracticable, particularly when it came to crossing trenches. It is not clear whether any attempt was made in this case to steer by articulation or whether Crompton's proposed " landship " was to be steered in this way in addition to being articulated. An even earlier " landship " design, in which Diplock had a hand, also had four tracks but apparently it had a rigid chassis and was meant to be steered by driving the tracks on each side at different speeds, i.e. by track slewing.[13] The same appears to have been the case with the only practical outcome of Crompton's " landship " work, a four-track experimental chassis with a rigid frame built in 1915, using Diplock's " Pedrail " tracks, which proved a failure.[14]

Nothing further was done about articulated tracked vehicles during the next thirty years, except for a small model experimented with by British forces in India during the early 'thirties.[15] One or two experiments were also carried out in Germany, France and Britain with trucks having their wheels replaced by tracks but, although the resulting four-track vehicles steered in a manner somewhat similar to that of articulated vehicles, they hardly belong to the same category.

Interest in articulated tracked vehicles did not revive until the late 'forties, when it sprung from two entirely different sources : one was the empirical development of special-purpose vehicles for operation in snow and the other was theoretical studies of soil-vehicle mechanics.

The first produced the " Sno-Cat " built around 1949, in the United States, by Tucker on the basis of the accumulated experience with several half-track-and-half-ski machines devised during the 1939–45 war. It was introduced successfully for public utilities maintenance work in the Rocky Mountains and subsequently attempts were made to

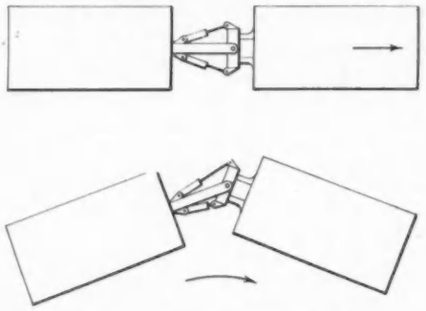

Fig. 5—Principle of steering by means of the W.N.R.E. " Polecat " type train joint

adapt it to military purposes but these proved abortive, for reasons which had nothing to do with the basic idea. Four " Sno-Cats " were also used by the 1957–58 British Trans-Antarctic Expedition and have already been described in connection with the latter.[16] In essence, it was a vehicle with a laden weight of 8,400 lb, four powered tracks and " four wheel " wagon steer.[6] Because of its exceptionally large surface contact area in relation to its weight, it had a nominal ground pressure of only 0·7 to 0·9 lb per square inch and this, combined with steering by articulation, produced a significant advance in performance over snow.

The second source of interest in articulated tracked vehicles was provided by M. G. Bekker, who advocated their development around 1948, while working on vehicle mobility in Canada, and during 1950-51 carried out a series of small-scale model tests in the United States at the Stevens Institute of Technology.[17] Later Bekker's ideas prompted the development by the Canadian Directorate of Vehicle Development of a small " bellyless " articulated carrier, the " Rat." The original model, evolved during 1955–56, proved highly mobile in snow and further development was undertaken by Canadair Limited, of Montreal. The Canadair version, designated the CL-61 Light Weight Articulated Snow Tractor, is shown in Fig. 1. It was designed in 1956 and the prototypes were tested in the winter of 1957. Of the six vehicles initially ordered by the Canadian Army, four had integral aluminium bodies and the other two had tubular steel chassis and glass fibre reinforced plastic bodies.[18] Subsequent models have had chassis frames consisting of a grid work of rectangular steel tubing and a water tight body of riveted aluminium sheet, the body and chassis forming an integral structural member. Under the influence of military air drop requirements, the chassis and engine mountings were designed using a load factor of 12g, which proved entirely adequate since subsequent parachute drops on a special platform showed that deceleration on impact never exceeded this figure.

The two units of the " Rat " are connected by a simple coupling on the centre line of the vehicle, below floor level, but the amount of relative angular movement in the three principal planes is restricted by two hydraulic dampers which splay out in a horizontal " V " from a single mounting on the front unit to the rear unit. Steering is accomplished by a cable and pulley arrangement, a drum at the bottom of a steering column taking in the cable on one side of the vehicle and paying it out on the other, which pulls in the rear corner of the front unit towards the corresponding front corner of the rear unit and thus alters the angle of articulation between them. The total angular movement in the horizontal plane is 80 deg. and the turning radius is about 9ft for an overall vehicle length of 14ft 6in.

In contrast to the original Directorate of Vehicle Development test vehicle, which had an engine in each of the two units, the " Rat " has a single 35 b.h.p. Volkswagen

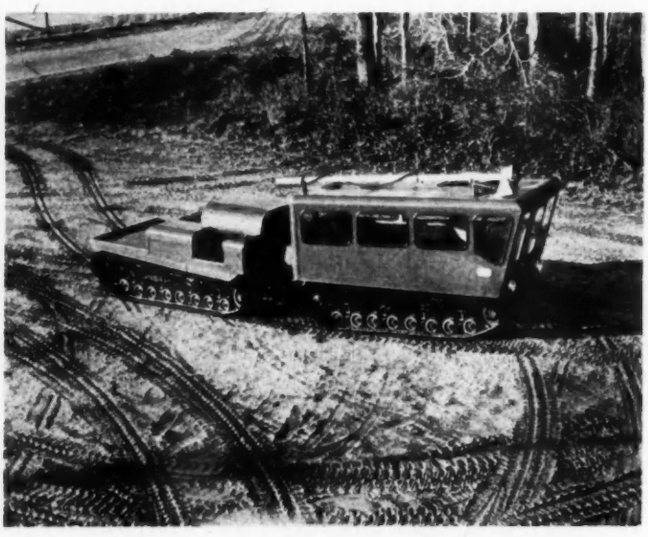

Fig. 3—Original model of the " Polecat " built by Wilson, Nuttall, Raimond Engineers in 1957

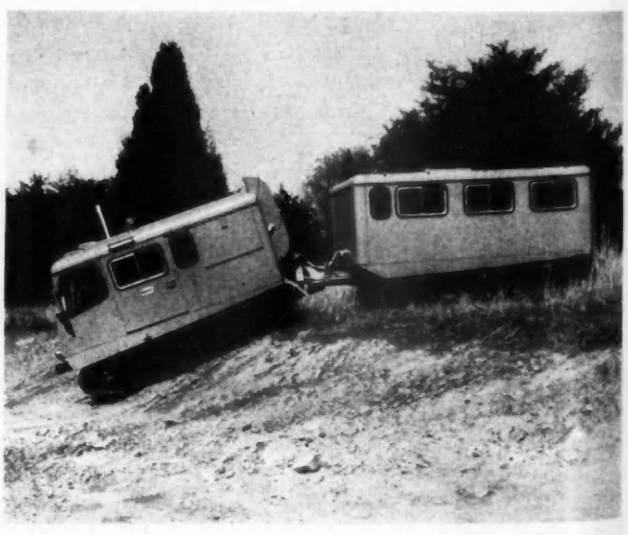

Fig. 4—Model 941 of the W.N.R.E. " Polecat " built for personnel transport in Greenland

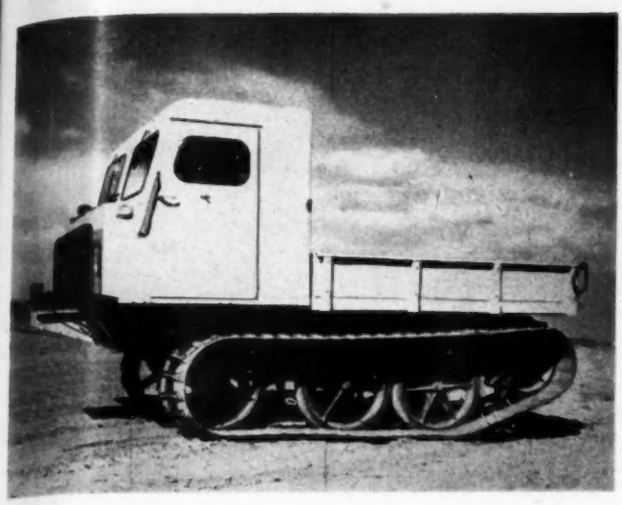

Fig. 6—Current model of the Nodwell "Scout" carrier

engine, mounted in the front unit, which drives all four tracks. Each track is made up of three conveyor-type rubber belts with connecting metal cross-bars or grousers and the tracks take up practically the whole of the vehicle width so that the "Rat" is "bellyless." This arrangement has reduced the nominal ground pressure to such an extent that at the maximum gross weight of 2,000 lb it is only 0·5 lb per square inch, or, in other words, about the same as that exerted by an average man on skis. The "Rat" has a maximum speed of 25 m.p.h. but in practice this is restricted by the absence of springing, other than that provided by the resilience of its pneumatic-tyred road wheels. It can also float in water and propel itself at up to about 3 m.p.h. by means of its tracks.

Since 1957 Canadair "Rats" have been successfully tested in the Canadian North, Alaska, Antarctic and several other parts of the world. During the course of their trials they have successfully negotiated swamps, tundra and muskeg, as well as snow-covered terrain, and have proved useful as light cargo carriers under the extremes of winter and summer conditions.

The performance of the "Rat" has recently led to the development of a similar model for the U.S. Army. This is the ¼-ton High Mobility Carrier, or CL-91, a model of which is shown in Fig. 2. The new vehicle is being designed and built by Canadair under the terms of a development sharing programme between the Canadian and U.S. Armies. Initially seven prototypes are to be delivered to the U.S. Army and three more will be built by Canadair for its own test purposes. As its American designation indicates, the CL-91 is to have a payload of about half a ton, and it is to be powered by a 65 b.h.p. Chevrolet "Corvair" engine located in the front unit. If desired, the front unit can operate independently of the rear section and the vehicle is expected to have a maximum speed of 30 m.p.h. on hard level ground but it is intended principally for use in difficult terrain.

Another line of development was started in the United States by Wilson, Nuttall, Raimond Engineers, Inc., of Chestertown, Maryland. The president of this company, C. J. Nuttall, had been with Bekker at the Stevens Institute of Technology and the company built its first articulated vehicle in 1957. This, called the "Polecat" and shown in Fig. 3, was based on a conversion of two "Weasel" carriers. These carriers were designed in 1942 in response to a U.S. Army requirement for a light cargo carrier capable of operating on snow and were used extensively during and since the latter part of the 1939–45 war, both in the standard M29 version and converted into the M29C amphibious carrier. Both had endless rubber-belt tracks and the M29, which weighed 4,925 lb laden, produced a nominal ground pressure of 2·1 lb per square inch. Most of the "Weasel" components were retained in combining two of them into the "Polecat" but a single engine, located in the rear unit, powered all four tracks, the drive to the front unit being taken by standard universally-jointed shafts through the centre of the connecting and steering joint. The design, of the train-type,[6] allowed complete freedom between the two units in roll and pitch but motion in the steering plane was at all times under full hydraulic servo control, and the manner of steering with this type of joint is shown diagrammatically in Fig. 5.

Tests with the "Polecat" in snow showed that it performed better than the parent vehicle and thus vindicated the concept of a two-unit tracked vehicle steered by articulation. In particular, the "Polecat" produced a drawbar pull 230 to 240 per cent that of the "Weasel" and was able to maintain speed in deep snow even while manoeuvring, whereas comparable skid-steered vehicles, which could compete with it when going straight ahead, lost headway and frequently became immobilised when turning. As a result of this encouraging experience, a redesigned "Polecat" was introduced by the U.S. Army in 1959 for high-speed personnel transport in Greenland and vehicles of this type have been used there with success ever since. They have demonstrated not only that their greater length leads to a better ride but also that, in spite of a 40 to 50 per cent increase in the average operating speed and a 20 to 25 per cent increase in unit weight, the life of tracks and suspension components is longer than in the parent skid-steered "Weasel."

The personnel carrier version of the "Polecat" is shown in Fig. 4. Its front unit, on the left, houses an International Harvester BD-264-6 6-cylinder engine of 122 b.h.p. net at 3,000 r.p.m. and a five speed synchromesh transmission, and provides seating for the driver and radio operator; the rear unit provides seating for six passengers. At full load the front unit weighs 6,600 lb. and the rear 7,000 lb, the corresponding nominal ground pressures being 2·1 and 2·2 lb per square inch., while maximum speed is given as 20 m.p.h. The overall width is 6ft 9in and length 26ft 5in but, in spite of this, the turning radius is 19ft.

While Wilson, Nuttall and Raimond Engineers, or W.N.R.E., were developing the "Polecat" for operation on snow, another company, the Robin-Nodwell Mfg., Ltd., of Calgary, Alberta, began to build a two-unit tracked vehicle for use by the Canadian oil industry in muskeg areas during the summer seasons, which had not been practicable with vehicles of any weight. It was not an articulated vehicle in the full sense of the word but consisted of a tractor, called the "Scout," and a companion separately powered trailer. However, the two units derived some advantage from each other and the whole combination emphasised the need to depart from conventional single unit tracked vehicle designs for successful operation in organic terrain, such as the Canadian muskeg.

Fig. 7—Nodwell RN-200 "Transporter"

The current version of the "Scout," the RN-21B, is shown in Fig. 6. It differs from the original RN-21 in having a strengthened frame and running gear, and wheels with solid rubber, instead of pneumatic, tyres—a surprising change in view of the general trend in this class of vehicles and the use of pneumatic tyres on other Nodwell models. However, in common with other vehicles, the "Scout" has wide continuous rubber belt tracks and a low nominal ground pressure, of 1·8 lb per square inch at the gross weight of 9,000 lb, but it also has one feature peculiar to Nodwell designs, namely rubber toothed driving sprockets.

Muskeg experience prior to the appearance of articulated vehicles has shown that, using nominal ground pressure as a rough index of performance, vehicles giving more than about 5 lb per square inch generally cut through the muskeg with their tracks and become immobilised. Vehicles with

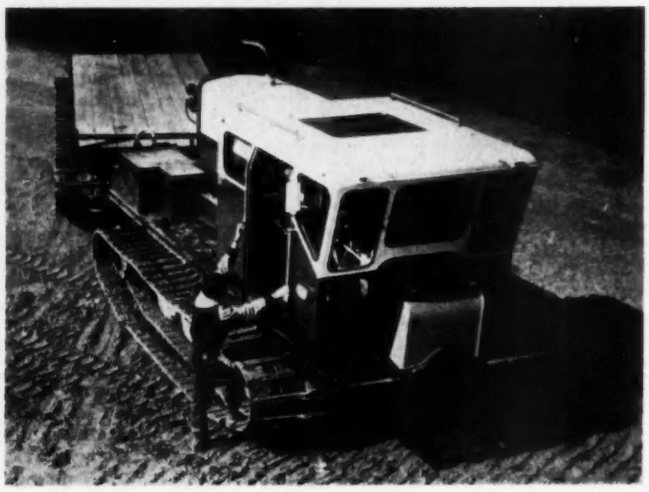

Fig. 8—W.N.R.E. "Musk-Ox" of 90,000 lb gross weight, the heaviest articulated tracked vehicle to date

ground pressures between 5 and 2½ lb per square inch have been able to operate in some cases over carefully picked routes but it is only when ground pressures are below 2½ lb per square inch that vehicles can operate with relative ease. Light special-purpose vehicles have been built, of course, with ground pressures of only about 2 lb per square inch, as shown by the U.S. Army's "Weasel" and the much more recent and successful amphibious M76 (originally T46E1) "Otter," built by the General Motors Corporation. But such low pressures can not be achieved with heavy vehicles of conventional design without resorting to impossibly wide tracks. In consequence, ground pressures of all but the lightest conventional vehicles remain relatively high. For instance, the lighter armoured vehicles average about 7 lb per square inch while battle tanks produce up to about 13 lb per square inch. Thus, to design heavy load carriers with ground pressures sufficiently low for muskeg operation it is necessary to adopt articulated construction, which makes it possible to keep the pressure low by increasing the total track length while track width remains within practical limits.

In consequence, the introduction of the original Nodwell "Scout" combination was followed by the construction of several articulated vehicles for muskeg operation. In 1957, for instance, Imperial Oil, Ltd., built an experimental articulated vehicle, called the "Centipede," by coupling two of the Nodwell powered trailers by means of a W.N.R.E. joint similar to that used on the "Polecat." The resulting twin-engined load carrier was rated at 5 to 6 short tons payload, compared with 2 to 4 short tons carried by the original Nodwell "Scout" combination, and its performance in summer muskeg operation was such that in 1958 Imperial Oil, Ltd., ordered another and even larger articulated vehicle from W.N.R.E., the "Musk-Ox."

In the meantime, the Robin-Nodwell Mfg., Ltd., introduced yet another articulated vehicle for muskeg operation, the RN-200, which was put into service by the Shell Oil Company of Canada Ltd., in 1958. This large "Transporter," shown in Fig. 7, weighs 34,000 lb and can carry a payload of 20,000 lb but due to its four 48in wide tracks its nominal ground pressure is only 1·9 lb per square inch at the gross weight of 54,000 lb. All four tracks are powered, the front two by an engine located under the cab and the rear two by a second engine mounted at the front of the load platform. Originally two 292c.in. Ford V-8 engines were used but these have now been replaced by GM 4–53 diesels, which are used with Allison "Transmatic" torque converter transmissions, giving the vehicle a maximum speed of about 10 m.p.h. Other features of interest include the tracks, each of which consists of two special 18in wide five-ply belts of nylon and cotton bonded with a rubber cover and cross bars of steel. The belts have proved very durable and the original set was used for three years without a failure. Track driving sprockets are of the Nodwell rubber tooth type and the road wheels have 7·50×20 pneumatic tyres: although the current specification still calls for steel cord tyres experience with several different types has proved that nylon and rayon tyres give the longest life and presumably these will be specified in the future. What is perhaps most interesting, however, is the method of steering, which is of the wagon type.[6] The front cab and track unit rotates under hydraulic control in the steering plane and is also free to pitch and roll in relation to the platform while the rear track unit is only allowed relative movement in the vertical plane. There are two hydraulic steering cylinders mounted under the platform and connected to the turntable of the front unit by heavy cables. With this arrangement the vehicle has a turning radius of about 25ft for an overall length of 39ft and a width of 10ft.

Three RN-200 "Transporters" have been used by the Shell Oil Company for three successive summer seasons to move drilling equipment and supplies across muskeg country. In the course of this they have successfully traversed all types of muskeg, with the exception of the "floating bog" variety with loosely consolidated peat covered with grassy vegetation and usually with water at the surface. In addition, the "Transporters" have traversed gravel bars and rock strewn areas and continued to be used successfully for a time after freeze up, until more conventional vehicles could take over. The transition period, with alternate freezing and thawing, proved to be the most difficult because of ice build-up on frames and running gear, and after freeze-up rough and rutted sections of the trail, frozen solid, were liable to cut the track belts rapidly.

The W.N.R.E. "Musk-Ox," which was built in 1959 and which is shown in Fig. 8, is the largest articulated vehicle so far. Its gross weight is 90,000 lb, out of which 28,000 lb are accounted for by the front unit and the remainder by the rear unit, which carries the whole of the 40,000 lb payload. The overall width of each is 10ft and the overall length of the whole vehicle is 48ft 7in, but for shipment the two units may be separated. The front unit, which carries a 375 b.h.p. Cummins NRTO–6 turbo-charged diesel and which has independently controlled brakes at the sprockets, can be run and manoeuvred on its own but the rear unit is dead when disconnected from the front unit. Normally the vehicle is steered by hydraulic actuation of the W.N.R.E. train joint by means of two Vickers cylinders of 6in diameter and 21in stroke, and the turning radius is 42ft.

In view of its weight, it is of some interest to observe that each track of the "Musk-Ox" consists of four nylon-rayon fabric belts covered with rubber, each belt being 8in wide and 1in thick, and has cast manganese steel shoes and magnesium backing plates. With conventional skid-steered tracked vehicles continuous rubber band type tracks are generally confined to much lighter vehicles. The overall width of each track is 52in and this results in a nominal ground pressure of 2·5 lb per square inch for the front unit and 3·4 lb per square inch for the rear unit, which is remarkably low considering the gross vehicle weight. The suspension is also of some interest as it consists of two walking beams on each side of the front unit and three on the rear unit, each beam carrying one trailing and one leading arm with a pneumatic tyred road

Fig. 9—"Cobra," the first three-unit articulated vehicle

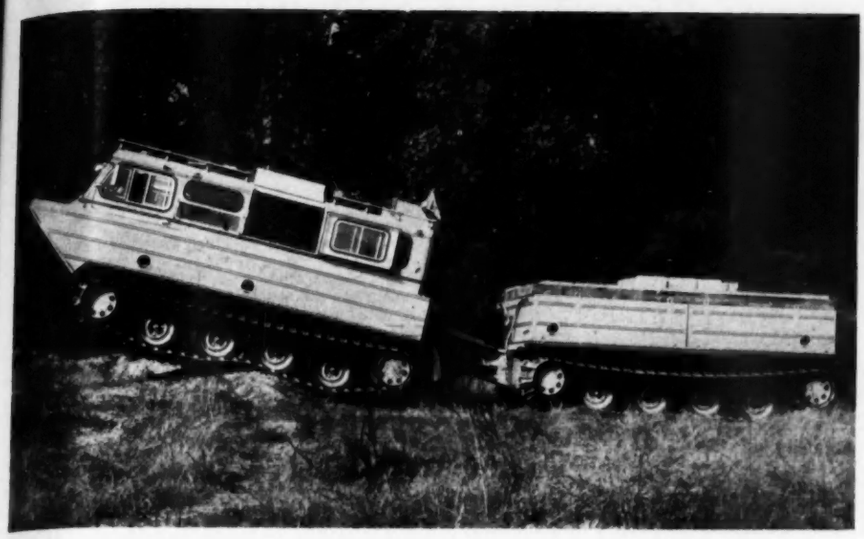

Fig. 10—Dynamometer-prototype of the " Terrapin " amphibious articulated vehicle

wheel. The smooth twenty-ply 9·00–15 nylon tyres are operated at an inflation pressure of 120 lb per square inch and this also happens to be the operating pressure of the General Tire 14in air pillows by means of which the road wheels are sprung and which are located between the arms and the walking beams. The air springs on both units are interconnected and there are levelling valves at the first, third and fifth bogie on each side, while other valves at the second and fourth bogies average the pressure between the two adjacent bogies on the same side. The combined effect of this type of suspension and the overall length of the vehicle is to produce a comfortable ride even over relatively rough terrain and the " Musk-Ox " is geared to a maximum speed of approximately 14 m.p.h. Altogether, the " Musk-Ox " is an exceptional vehicle, not least, perhaps, for the fact that in the first two summer seasons of difficult muskeg operation it successfully logged 13,000 miles. Some of the operational background and the early experience with the vehicle have already been described elsewhere.[19].

Three other articulated vehicles have been built more recently by Wilson, Nuttall, Raimond Engineers, each showing novel or different features. One is the " Cobra " three-unit articulated vehicle built for the U.S. Army Ordnance Tank-Automotive Command and shown in Fig. 9. This experimental vehicle represents the first attempt to extend the principle of articulated construction beyond two units and is powered by a single engine mounted in the front unit. All six tracks are powered at all times through a drive line with five differentials, two of which can be locked out by the driver. Steering is by two W.N.R.E. joints but normally only one joint, between the first and second unit, is used and the second trails freely. However, when the hydraulic pressure in the first joint system reaches about 800 lb per square inch, when the vehicle is executing tight turns for instance, the second joint is brought into play by pressure sensitive valves and helps the action of the first joint by turning in the opposite sense. This action might be clarified by considering the three units standing in line and the effect of operating the first joint only, which will tend to rotate each unit in place so that each joint turns in the opposite sense and the units form an " S " ; it is this motion which the second joint is designed to assist. The actual turning radius of the 42ft 8in long vehicle is about 30ft and in practice the steering system has proved satisfactory, with the sucessive units tracking the first closely even when snaking along narrow trails. Moreover, experience with the three-unit " Cobra " is said to have shown that the running gear can carry greater loads than in a two-unit vehicle because of lower working stresses.

The track assembly of the " Cobra " provides, in itself, a further point of interest as it embodies spaced-link tracks. These it inherited from the T60 amphibious carriers from which the three units of the " Cobra " were, in fact, modified. The T60 was a vehicle of the " Weasel " class designed to explore the use of spaced-link track which had been advocated by Bekker[20] and first demonstrated in the " Ground Hog " built during the late 'forties. It proved, as expected, superior to the " Weasel " in straight ahead motion in muddy terrain but the wide spaced-link tracks proved incompatible with skid-steering. This led to the conversion of the T60 experimental carriers into the units of the " Cobra " and the resulting combination of spaced-link tracks with articulated steering produced a practical vehicle of great promise for operation in difficult terrain.

The second of the three vehicles developed recently by W.N.R.E. is the " Polecat " Mark II. The prototype of this vehicle, shown in Fig. 10, has been running since October 1960 and has been renamed the " Terrapin " by the U.S. Army Transportation Research Command. It is a two-unit amphibious dynamometer vehicle with an overall length of 37ft 7in and a gross weight of 25,000 lb, which produces an average nominal ground pressure of 1·7 lb per square inch. A single 150 b.h.p. V–8 Chrysler engine located in the front unit drives all four tracks and with a five-speed synchromesh transmission the " Terrapin " is capable of a maximum road speed of about 35 m.p.h., while in water it can propel itself by means of its tracks at up to 3 m.p.h.

Two features of the " Terrapin " which call for particular attention are the method of articulation and the track assembly. The articulation joint is of the usual W.N.R.E. " Polecat " type with two 3½in bore 19in stroke hydraulic cylinders and allows up to 35 deg. of movement in either direction in the horizontal plane, which gives a turning radius of 38ft. However, in contrast to the earlier designs, there is also a third cylinder which provides damping in the vertical plane and makes the total length of the vehicle more effective from the point of view of ride over rough terrain. Ride is further improved by a new suspension with hydro-pneumatic springing and four road wheels on trailing arms on either side of each unit. In contrast to the original " Polecat," as well as the " Weasel " and the " Cobra," the " Terrapin " has special pneumatic tyres, which have been adopted increasingly frequently in place of solid rubber tyres for vehicles intended for operation on snow and marshy ground since the 1939–45 war and which have already been used on the M76 carrier, Nodwell's vehicles and the W.N.R.E. " Musk-Ox." The 35in wide tracks are also of the continuous band type now commonly used in soft ground vehicles and there are two 10in wide nylon and rayon reinforced rubber belts for each track with forged aluminium alloy track shoes swaged-bolted to the belts. The sprocket is unusual, however, in that it has nine rubber mounted roller teeth, a commendable design feature which reduces the possibility of sliding between mating surfaces and which recalls the roller sprockets of the half-track vehicles used extensively by the German Army during the 1939–45 war.

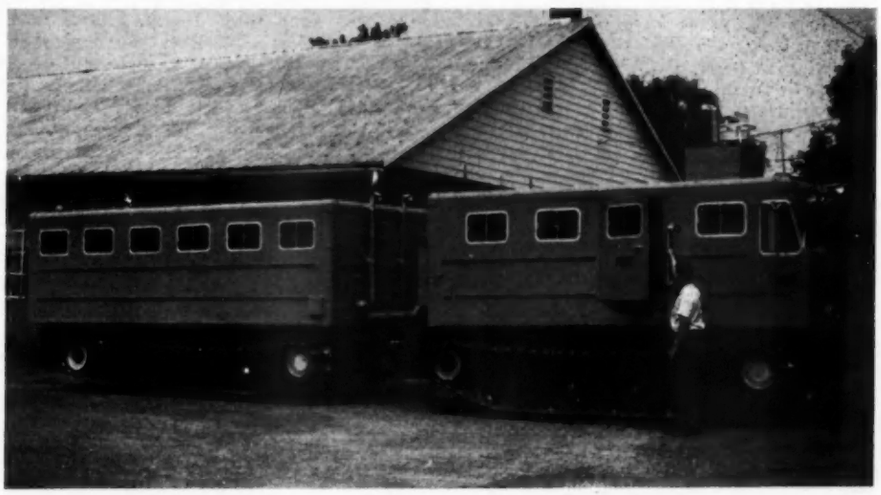

Fig. 11—W.N.R.E. " Polecat " Mark II, 35-passenger Arctic personnel carrier

The " Terrapin " was built mainly for research work but the same chassis has been used since for the " Polecat " Mark II

Fig. 12—" Dinah " light general-purpose tracked vehicle designed for operation in difficult terrain

35-passenger arctic personnel carrier. This vehicle is shown in Fig. 11 and it has recently gone into service in Greenland, where it supplements the original and smaller " Polecats." It has a gross weight of 31,500 lb and is powered by a 194 b.h.p. turbo-charged Hercules diesel but in essence its design is similar to that of the " Terrapin," except that it is not amphibious.

The latest articulated vehicle produced by Wilson, Nuttall, Raimond Engineers is the " Dinah " shown in Fig. 12. This is a small general-purpose vehicle capable of carrying a total load of 1,200 lb, excluding the driver. It has a gross weight of 5,000 lb and is 17ft 4in long overall. The lower part of the hull of each unit is of welded low alloy steel construction but the upper part is of glass fibre reinforced plastic and the vehicle will float without additional buoyancy or preparation. All four tracks are driven by a single 42 b.h.p. two-cylinder Panhard engine located in the front unit, and the vehicle is capable of a maximum road speed of the order of 16 m.p.h. and can propel itself in water by means of its tracks at up to about 2 m.p.h., which is sufficient to cross still water. Higher water speeds may be obtained using an outboard motor for which a mounting bracket is provided.

As in the case of the " Terrapin," steering in water, as well as on land, is by articulation and the joint is of the now well-tried W.N.R.E. " Polecat " type. However, only one 2½in bore 8in stroke cylinder is sufficient for control in the steering plane but there is a second cylinder of the same size in the pitching plane, which is normally locked for water operation and which acts as a heavy damper on land, improving the ride as in the case of the " Terrapin " and the " Polecat " Mark II carrier. The turning radius on land is 19ft 6in.

In other respects the " Dinah " also follows practice successfully adopted on earlier W.N.R.E. vehicles. Its tracks consist of nylon and rayon reinforced rubber belts with swaged-bolted steel shoes and are driven by sprockets with ten nylon rollers. The tracks are 20in wide and at full load give a nominal ground pressure of only 1·55 lb per square inch. Each of the two units has three road wheels per side independently sprung by means of trailing arms and Neidhart rubber springs, and having 8·00×6 pneumatic tyres.

Thus, the range of articulated tracked vehicles now extends from the 40-ton " Musk-Ox " down to the 2-ton "Dinah " and the even lighter 1-ton " Rat." Such a wide range of sizes provides ample evidence of the capabilities of this type of vehicle and in particular of its superior performance in snow and difficult marshy terrain. So far articulated tracked vehicles have been developed chiefly for operation under such particularly difficult conditions, where the need for them is greatest. But there is no reason why the application of this form of construction should not be extended to other fields, where it can offer the advantages of longer, narrower chassis, with all that this implies in terms of reduced resistance to motion and ground pressure, a better ride, and reduced soil stresses and power losses during steering. Application to armoured fighting vehicles presents difficulties because of the vulnerability of the joints and the hull shapes which go with them. In addition, articulated tracked vehicles can not make pivot turns and in general have larger turning radii than existing skid-steered vehicles. However, in several other fields the turning radius or silhouette of articulated tracked vehicles should not present any major problem and should be more than balanced by their other characteristics. This applies in particular to cross-country cargo carriers which are now receiving some belated attention.[21]

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Technical Reports

A Non-Destructive Method for Measuring the Elastic Anisotropy of Wood Using an Ultrasonic Pulse Technique. By I. D. G. Lee, B.Sc. (Eng.), A.I.W.Sc. Timber Development Association, Ltd. (Research Report E/RR/9). Price 3s. 6d.—This report gives details of a method of testing alternative to static loading and slow vibration and, by the method outlined, it is possible to use the same specimen for all measurements in any one plane. Thus, extraneous variations resulting from irregularities of growth are greatly reduced. Elastic constants are determined by measuring the velocities at which three types of plane wave travel in known directions. The most convenient method was found in measuring the time taken for the onset of an ultrasonic pulse of longitudinal waves to travel across the diameters of a disc, each disc cut so that its circular face lay in the plane in which varia ions in the elastic modulus were to be measured. In the report, Mr. Lee effects a comparison between values of Young's modulus derived from wave velocities and theoretical values based on the assumption that wood possesses rhombic symmetry. Differences in velocity distribution in the end grain section (radial tangential plane) between hardwood and softwood species are discussed in relation to wood structure.

A Comparison of Methods for Measuring the Mean Velocity of Rivers. By Sheena G. M. Todd and J. Whitake. (Fluids Note No. 95.) Department of Scientific and Industrial Research National Engineering Laboratory, East Kilbride, Glasgow. No price quoted.—The discharge of rivers, when measured by velocity-area methods, is usually determined from a restricted number of point velocity measurements on each vertical, since complete velocity distribution traverses are often impractical because of changing stage. The accuracy of nine of these reduced-point methods is examined by comparing the results with the mean velocity obtained by planimetering fifty-six actual profiles plotted from three river gaugings in Holland, Italy and Russia.

The single point methods (at 0·6 depth and at 0·5 depth, times a factor 0·96 in the latter case) are shown to have mean standard deviations of over ±3½ per cent, with, in addition, significant permanent errors caused by systematic bias. The two and three point methods have mean standard deviations of about ±2 per cent, while the five and six point methods vary from about ±1 to ±2 per cent from the true mean velocity.

An Improved Batching Counter. By D. Nairn. D.S.I.R. National Engineering Laboratory.—A batching decade counter is described which enables commercial transistor decades to be used at their maximum counting frequency. It employs a simple diode network which recognises when a count of 998 is reached and causes the succeeding pulse to be gated to give out a batch pulse and generate a reset pulse. This action resets each decade of the counter to the nines complement of the required batch number. The main advantage of the counter arises from the fact that when the count changes to 998 only the least significant decade is involved so that all transient delays are settled within twenty-four microseconds (two microseconds delay in the first binary stage of the counter and twenty-two microseconds reset period). In normal methods used for batching there are unavoidable delays before it is known that a reset pulse is to be generated, and these limit the maximum frequency of the counter.

A Fast Adding, or Subtracting, Transistorised Counter for Simultaneous Action from Two Random, or Periodic, Pulse Trains. By W. H. P. Leslie and D. Nairn. D.S.I.R. National Engineering Laboratory.—This report describes a series of circuits, each constructed as a separate plug-in unit, which can be assembled to make straight or reversible counters. Their two main features are a high speed of count propagation through a binary or binary decimal counter, and an ability to deal with random pulses on each input line irrespective of the degree of overlap or separation of the pulses. The speed is such that an output pulse is available in two microseconds from commercial binary units having resolution times of ten microseconds, despite the fact that all twenty units in a five-decimal digit counter are being switched.

Instrument Ball Bearings. By P. J. Geary. British Scientific Instrument Research Association, South Hill, Chislehurst, Kent. Price 21s.—This is the fourth booklet of a series entitled " A Survey of Instrument Parts." During the past ten years the production of instrument ball bearings has greatly increased, while refinements in manufacturing techniques have made available bearings of greatly enhanced performance. The present publication offers a concise review of their characteristics and utilisation. Aspects of the subjects dealt with include tolerances, truth of running, avoidance of vibration and noise, frictional torque, lubrication, load capacity and life. The publication contains thirteen line diagrams and a bibliography of 144 references.

THE ENGINEER

TECHNICAL CONTRIBUTORS SECTION

NOVEMBER, 1961

Gear Tooth Pitting and Fatigue Strength*

By B. A. SHOTTER†

The mechanism of gear tooth pitting has been under investigation for at least twenty-five years, but, as yet, there has been no conclusive evidence as to the basic cause of the phenomenon. It has become generally accepted that it is probably some form of fatigue failure although it appears to differ from conventional forms of fatigue in a number of ways. One major point of difference is that a lubricant appears to be necessary for pitting to occur and S. Way (1940)[1] showed that the role of the lubricant was to assist the propagation of the crack. This was proved by drilling a small hole into the cracked region of an incipient pit which thereafter failed to develop. A second point of difference lies in the fact that whereas the S/N characteristic of steels under normal fatigue conditions have a knee in the vicinity of 10^6 cycles, there is no universal agreement as to whether pitting curves do have a knee at all. Some experimenters have reported a knee but others seem certain that no knee occurs before 2×10^7 tooth contacts. It is here shown that despite these differences, pitting of the kind found on gear teeth is very similar in character to conventional fatigue.

Asperity Contacts and Pitting

WHEN considering gears theoretically, they are usually treated as perfect geometrical surfaces. However, gear teeth are only approximations to the required surfaces both as regards the generating action and the metal cutting process. Thus a gear tooth can be considered as a perfect surface with asperities of various heights superimposed. When two gears are meshed together some asperities on one surface will touch those on the other. As the gears start to rotate, the initial asperity contacts will separate and the load be transferred to others. Since the topography of each tooth will in general be different, an asperity which carries a load during one contact may or may not do so during subsequent tooth contacts. Even when the asperity does contact another asperity on an opposing tooth the load between them is unlikely to be the same as that at first contact. Only when a complete cycle of tooth contacts has occurred will the two original asperities again contact one another. In a complete cycle there will be one contact of this particular asperity which will be more highly stressed than the others. This contact will then be the important one as regards the initiation of a pit crack.

Using the above concept on a particular gear pair having numbers of teeth t and T, on pinion and wheel respectively, it is evident that the stress cycles per minute relevant for pitting should be $N/t=n/T$, where N and n are the revolutions per minute of wheel and pinion, providing there is no common factor in the tooth numbers. If a common factor c exists then the relevant number of "asperity stress cycles" per minute can be expressed as :

$$\text{a.s.c.}=\frac{Nc}{t}=\frac{nc}{T} \quad . \quad . \quad . \quad . \quad (1)$$

Taking as a simple example the case of 1 : 1 ratio gears :

$$T=t=c$$

Therefore

$$\text{a.s.c.}=N=n$$

Thus in this case only is the relevant number of stress cycles per minute equal to the revolutions per minute of the gear. In all other cases the stress will be less frequent.

To test whether this hypothesis is helpful in analysing pitting, an article by A. Sykes (1959)[2] has been used as a source of practical gear information. In this article he develops

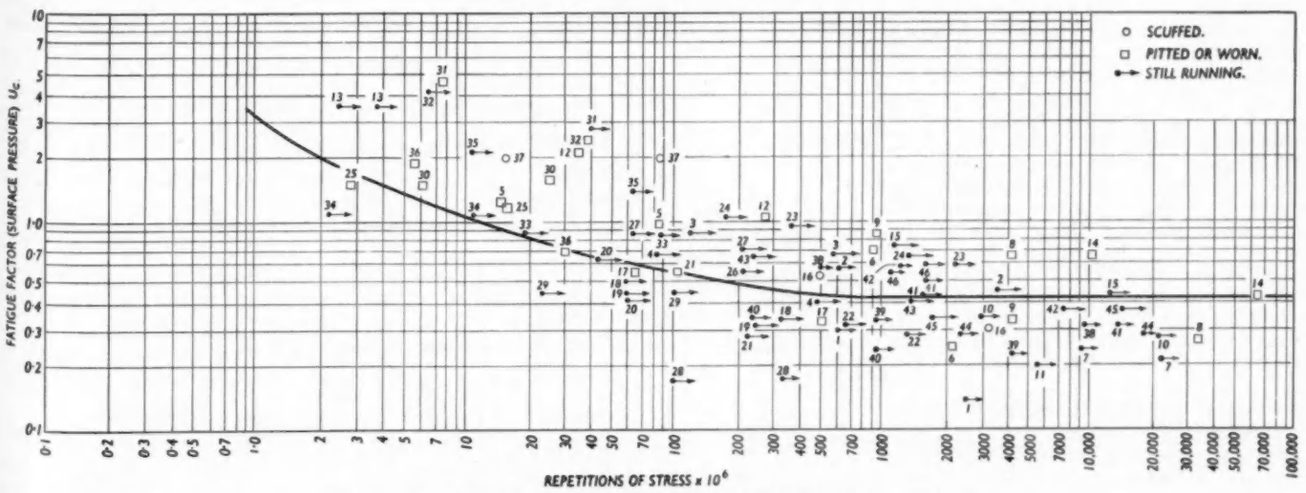

Fig. 1—The Sykes fatigue factor plotted against tooth contact stress repetitions

* An abridged version of this article was given as a lecture by the author to the Fifteenth Annual Conference of the Stress Analysis Group of the Institute of Physics and the Physical Society, on April 27, 1961, at Southampton University.

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Technical Contributors Section (*Continued*)

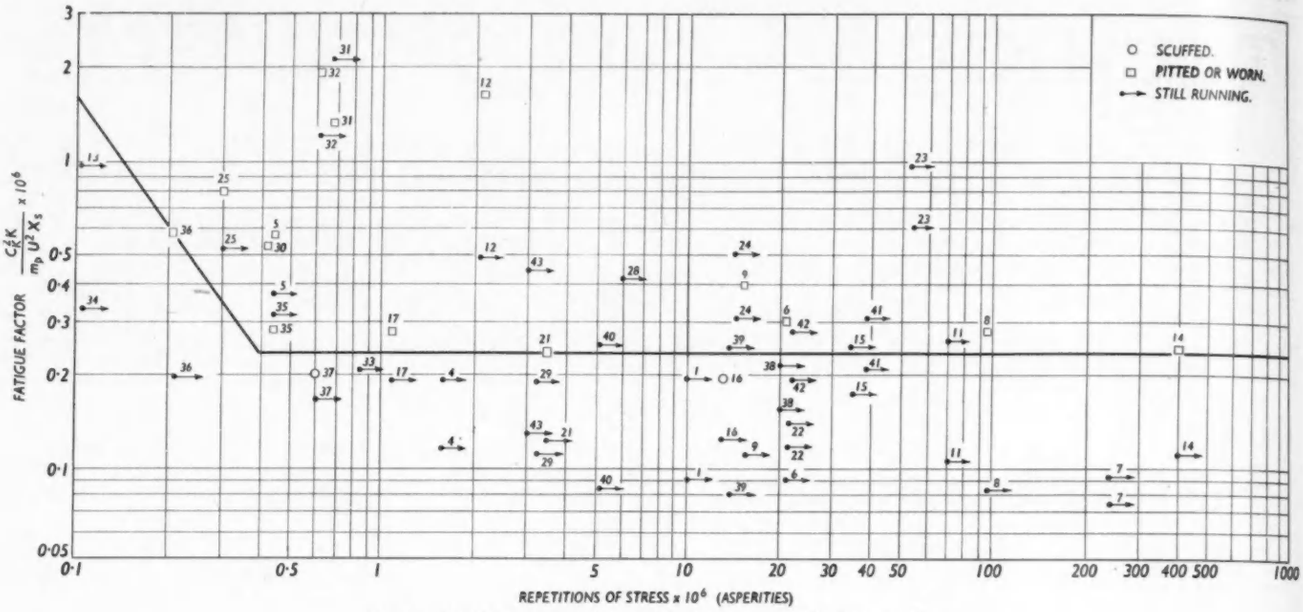

Fig. 2—The Sykes fatigue factor plotted against asperity stress cycles

a fatigue factor (U_c) which is a function of the surface loading of the gear teeth. Fig. 1 is taken from the article and shows a plot of U_c against numbers of revolutions of the appropriate gear. If the abscissa is modified as suggested above, the plot of Fig. 2 is obtained. Although the height of the scatter band is not greatly modified, the main point to note is that the points can now be said to lie on two lines whose intersection occurs at about 10^6 cycles. This trend is very similar to a typical S/N curve for steels where a knee is usually expected at about 10^6 cycles on a log/log plot. Such a result certainly suggests that it may be possible to consider pitting as more closely akin to conventional fatigue than has been the case previously. A reappraisal of past work may show whether this concept can be universally applied to pitting.

The idea that " asperity stress cycles " are important would explain why the " hunting tooth" ratios used by gear engineers can have a beneficial effect on pitting. A hunting tooth ratio is one which, instead of reducing to a simple fraction, differs therefrom by having one extra tooth, usually on the wheel. Now looking back to Equation (1) it can be seen that the number of stress cycles per minute can be kept at as low a value as possible for a given value of revolutions per minute by making c small and t large. The hunting ratio helps by ensuring that the only common factor (c) is unity. But it can also be seen that the larger the tooth numbers the greater the time before pitting is likely to start. This will be particularly important on gears that are being designed for a finite life, where the number of allowable asperity stress cycles would not exceed 1,000,000. If there is no common factor, and pitting is the criterion for failure, then the total number of revolutions the gears can make will be directly proportional to the number of teeth.

Pitting and Ultimate Tensile Strength

A paper by W. T. Chesters[3] at the International Conference on Gearing held at the Institution of Mechanical Engineers in 1958 presented pitting results from experiments using rolling discs. The results showed S/N curves of conventional form indicating a limiting load below which pitting did not occur. If the pitting limit stress at the disc contact is expressed in terms of the maximum Hertzian compressive stress (S_H) and then plotted against the ultimate tensile strength (U) of the material, the graph shown in Fig. 3 is obtained. It can be seen from this log/log plot that the pitting limit stress is proportional to the u.t.s. of the material. The equation of the line is approximately :

$$S_H = 1{\cdot}13U \quad . \quad . \quad . \quad . \quad (2)$$

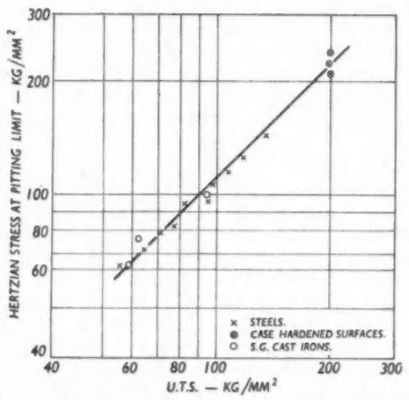

Fig. 3—Pitting limit plotted against ultimate tensile strength

This interesting result cannot be applied directly to gear design because the surfaces of the discs used for these tests were cylindrically ground and were much smoother than those normally found on gear teeth. Some effects of different surface finishes on the behaviour of discs have been demonstrated by Shotter (1958).[4] In addition the motion at the generalised contact between gear teeth involves sliding whereas Chesters tests were conducted under almost pure rolling conditions. Crook (1958)[5] has shown that sliding tends to reduce the oil film thickness which would make surface roughness even more important.

Fatigue Tests and Ultimate Tensile Strength

Since it has been postulated that repeated stressing of asperity contacts is responsible for initiating pits, it is necessary to consider

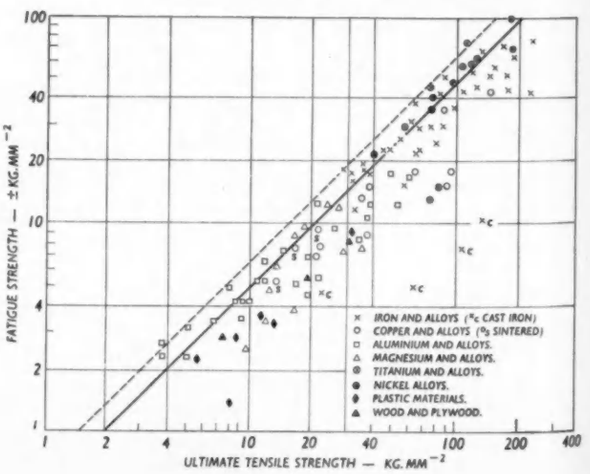

Fig. 4—Fatigue strength of various materials plotted against ultimate tensile strength

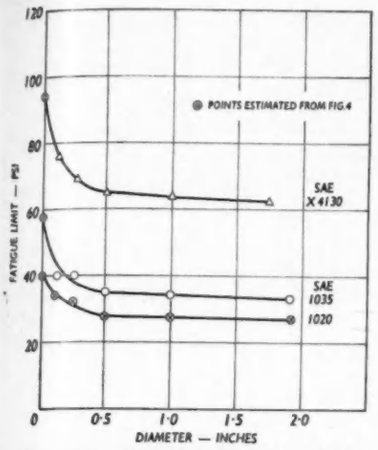

Fig. 5—Size effect in fatigue (Markovin and Moore)

general fatigue behaviour with particular reference to small elements of material.

Although it was found by Chesters that, for pitting, the limiting stress was proportional to u.t.s., general fatigue tests on steels are not usually amenable to such a simple law, except at low u.t.s. values where the fatigue limits of steels are approximately proportional to u.t.s. In an attempt to arrive at a relationship between fatigue strength and u.t.s., published fatigue limits from Wöhler tests have been plotted against this variable on a log/log scale. The points plotted were not restricted to steels but covered a wide range of materials as shown in Fig. 4. Naturally the number of points plotted here is limited, but particularly high and particularly low values have been included in each alloy group. As can be seen there is a general slope of 45 deg. indicating that the fatigue strength is proportional to u.t.s. The solid line represents the equation :

$F = U/2$, where F = maximum stress at fatigue limit.

The dotted line marking the upper limit of the points represents :

$$F = 0{\cdot}67\,U \quad . \quad . \quad . \quad . \quad (3)$$

This sort of result has been reported previously (e.g. Cazaud 1948),[6] but the log/log presentation enables fatigue limits from a wide range of u.t.s. values to be plotted on a single graph.

Now it is well-known that with fatigue tests there is a size effect such that small specimens tend to have higher fatigue limits. Typical results are those of Markovin and Moore (1944)[7] which are shown in Fig. 5, together with points taken from the dotted line of Fig. 4 on the zero of the size axis. As can be seen, it is fairly easy to draw smooth lines through these points. Additional evidence towards the conclusion that very small specimens may be expected to have the fatigue limits predicted by the dotted line can be found by observations on the influence of the metal condition. In size effect experiments, it has been noticed that annealed specimens tend to have a much flatter curve than those that were cold worked or quenched from a high temperature. Similarly, in Fig. 4 the points near the dotted line tend to be those from annealed specimens. Thus the more nearly perfect the material, the closer the fatigue results seem to get to this line.

One important difference between the measurement of u.t.s. and the fatigue test is that the tensile test does really take an average of the material properties. The fatigue test is likely to stress a large number of surface grains, but the initial crack will start from the weakest point. The subsequent stress raising effect of the crack will ensure that it is propagated through the specimen. It, therefore, follows that the u.t.s. of individual grains may well have an important bearing on the fatigue limit of a particular material. Microhardness tests give a measure of u.t.s. over very small areas, so perhaps minimum microhardness values would give better correlation with fatigue results than bulk u.t.s. values.

Gear Tooth Pitting

In Wöhler tests the total stress range is twice the maximum stress value. Thus if S is the total stress range we may modify equation (3) as follows :

$$S = 1{\cdot}34\,U \quad . \quad . \quad . \quad . \quad (4)$$

This is very similar to equation (2) where the Hertzian stress value is also the total stress range on an element of metal. The similarity of equations (2) and (4) is sufficiently good to suggest that it is in fact a similar law that is being obeyed in both cases. This would imply that for idealised simulated gear tooth contacts the pitting stress can be related to the stress levels in conventional fatigue tests. In practice gears are known to pit at lower stress levels than those predicted by the disc machine tests. This is not surprising when it is considered that the initial surface roughness of a single gear tooth is perhaps three or four times the equilibrium oil film thickness between a pair of teeth.

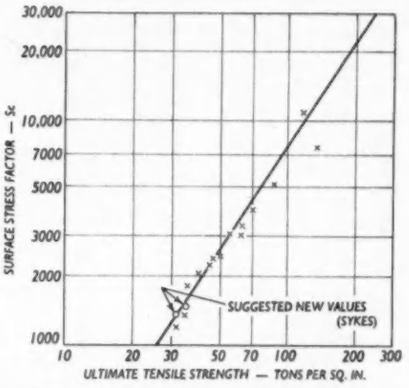

Fig. 7—Relationship between surface stress factor and ultimate tensile strength (B.S.S. 545)

Although the nature of the stresses on asperities is uncertain it could be postulated that the law relating the pitting limit to u.t.s. might be similar for different surface finishes. Now for involute gears the Hertzian stress

$$S_H = C\sqrt{\frac{K}{m}}$$

where K is the conventional "K factor" widely used to describe gear loads and C and m are constants dependent on the gear design. However, C and m both change comparatively little, so to a first order approximation

$$S_H \propto \sqrt{K}$$

i.e.

$\frac{K}{(S_H)^2}$ should equal a constant.

But, if the Hertzian stress is proportional to u.t.s. at the pitting limit, then $K/(U)^2$ should equal a constant.

If the examples given by Sykes are used to

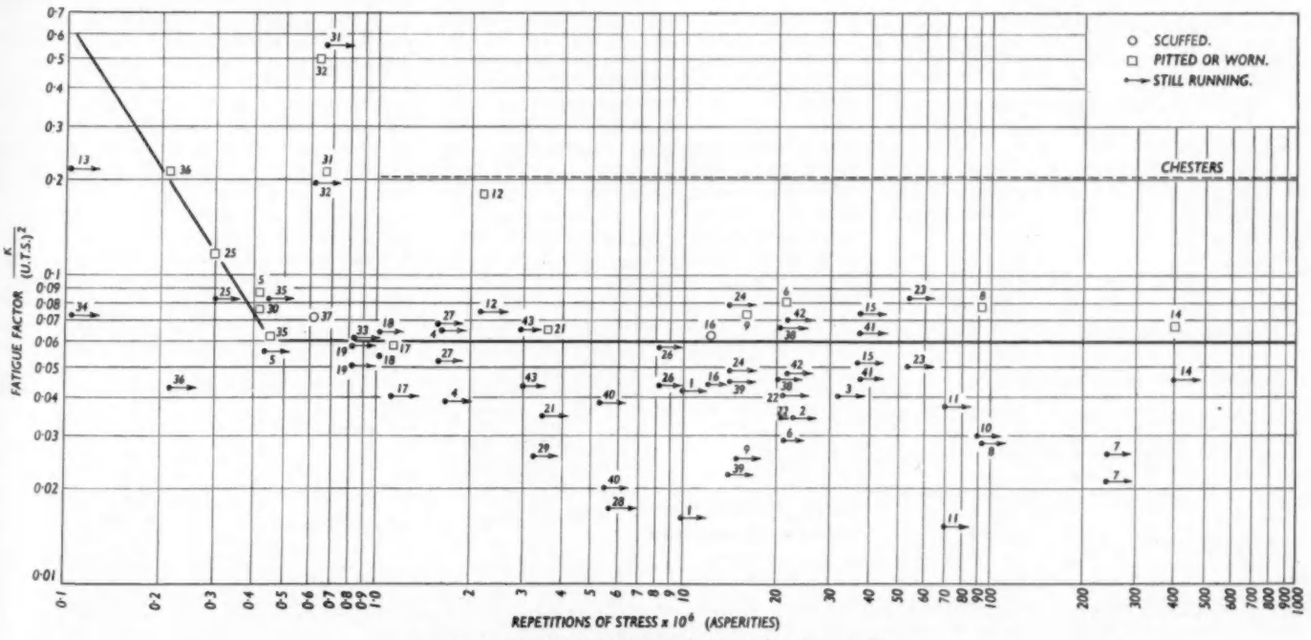

Fig. 6—Load/(U.T.S.)² plotted against asperity stress cycles

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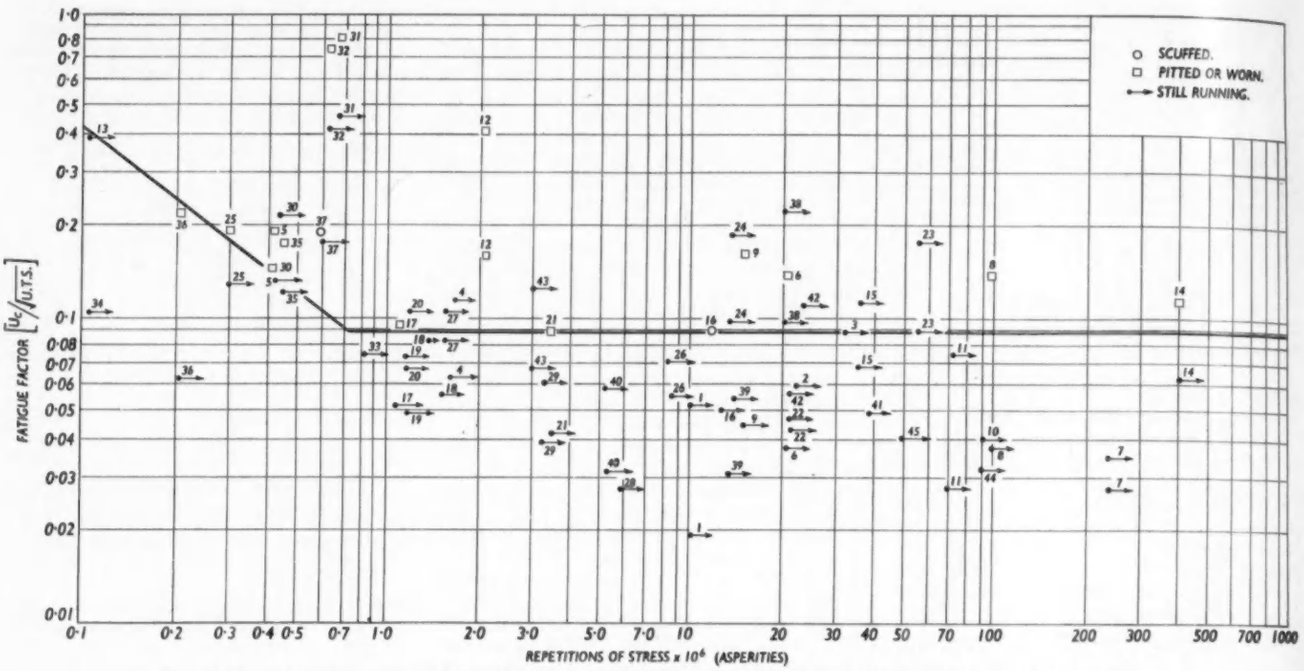

Fig. 8—The Sykes fatigue factor divided by the root of the ultimate tensile strength plotted against asperity stress cycles

derive the above quantity and the results plotted against asperity stress cycles, the graph shown in Fig. 6 is obtained. The full line has been drawn in to define a lower limit to the failure points and the horizontal portion is $K/U^2=0{\cdot}06$, where U is in tons per square inch. In general the differentiation between failure and success points is very good and the form of the line very similar to a conventional S/N curve. Some degree of variation is to be expected in the position of the horizontal line for a number of reasons. First, the nominal load on a gear tooth may be considerably modified by dynamic loading and therefore the application should be taken into account. Secondly, surface finish and gear accuracy will cause differences in the pitting limit. Thirdly, as previously mentioned, gear geometry can introduce differences in the Hertzian stresses at the tooth contact. Fourthly, no account has been taken of the velocity of the surfaces. This, together with the oil viscosity, is likely to affect the equilibrium oil film thickness and hence the pitting limit. The dotted line incidicates the value to be expected from Chesters results.

The position of the left-hand end of the line is also likely to move as conventional S/N fatigue curves show considerable variation in the slope of this line and its intercept with the horizontal for different steels. However, for an infinite gear life, the design should be such as to give a loading below the horizontal line. Where finite lives are required the position of the left-hand part of the line would need to be known with greater accuracy, but perhaps conventional fatigue tests would suffice for this.

It is interesting to compare the material factor used by Sykes in his Fatigue Factor (U_c) with the $1/(\text{u.t.s.})^2$ that has been used here. The factors used by Sykes are similar to those in the British Standard 545 and are mainly based on conservative experience. If these values (designated S_c) are plotted against the ultimate tensile strength, a trend can be seen and a straight line has been drawn having a slope of $1\frac{1}{2}$ which lies fairly close to all the points (Fig. 7). This suggests that the factor used by Sykes is rather too small and that a better degree of correlation would be obtained if his values for U_c were divided by the square root of the u.t.s. In Fig. 8 this has been done and, as expected, the differentiation between success and failure points has been considerably improved.

The S_c values suggested in the British Standard for case hardened materials tend to have appreciable scatter. A possible explanation may be the fact that different amounts of metal ground off may expose lower hardness regions where failures could start. This will be particularly important where the hardness gradient changes rapidly.

The Sykes Fatigue Factor also includes a speed factor which is determined as a function of the sum of the pinion and wheel revolutions per minute. From a fundamental point of view this is not satisfactory. Crook (1958)[5] has shown that the oil film thickness at simulated gear tooth contacts varies as the cube root of the surface speed. However, the surface speed of gear teeth is approximately proportional to their pitch line speed, so that the pitch line speed can be related to the oil film thickness. Reverting to the data provided by Sykes the cube roots of the pitch line speeds have been plotted against the sum of pinion and wheel revolutions per minute in Fig. 9. Although there is a considerable scatter it can be seen that the general trend is approximately parallel to the Sykes speed factor X_c which is the result of experience. It thus appears that laboratory experiment and practice are suggesting a speed factor proportional to the cube root of the pitch line speed. As speed is progressively reduced a greater proportion of the load will be carried by asperities rather than by the hydrodynamic oil film. Therefore below some

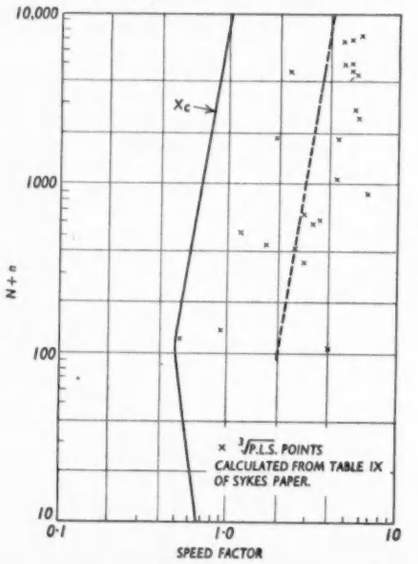

Fig. 9—Comparison between X_c and $\sqrt[3]{\text{P.L.S.}}$ plotted against sum of pinion and wheel revolutions per minute

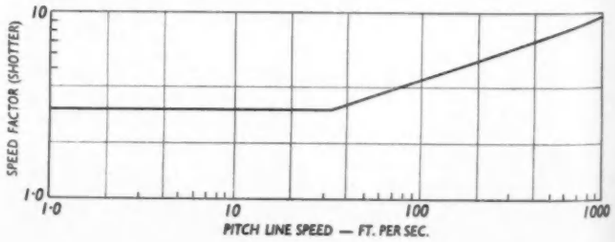

Fig. 10—Suggested speed factor plotted against pitch line speed

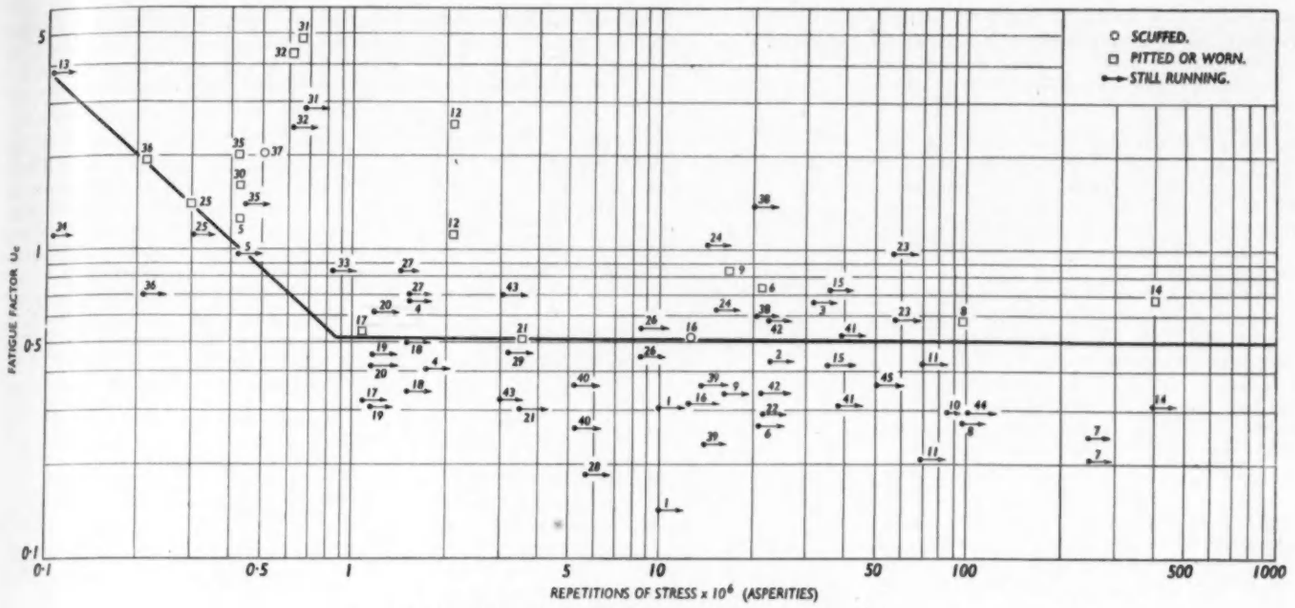

Fig. 11—Fatigue factor plotted against asperity stress cycles

speeds, there may be no need for a variable speed factor. By applying this concept to Fig. 6 it was found that a constant speed factor appeared satisfactory at pitch line speeds below about 35ft per second. It is therefore, suggested that in gear loading formulae the speed factor shown in Fig. 10 may give reasonable results. The simple loading formula which may prove to be satisfactory is :

$$L_c=\frac{K}{U^2}\ (=\text{constant, for infinite gear life}).$$

A rather more elaborate formula which takes into account some changes in gear design and speed would be

$$L_c=\frac{C_k^2K}{m_pU^2X_s}\ (=\text{constant, for infinite gear life})$$

where C_k and m_p can be determined from values given in *Practical Gear Design*, by D. W. Dudley (page 51).[8] However, Fig. 11 shows that this formula does not appear as satisfactory as the simple one.

Additional evidence to show that pitting is closely allied to normal fatigue has been found in experiments on gears in a laboratory test rig. In conducting tests into the nature of pitting it has been the author's policy not to rely on the observation of the first pit as being evidence of surface failure but to continue tests until a large number of pits have appeared. It is then possible to plot the number of pits against time and from this to obtain both the intercept of this line with the time axis and also the rate of pit formation with time. Fig. 12 shows typical results, whilst Fig. 13 demonstrates the danger of observing the first pit only. It is clear that in this second case the initial pits did not conform to the general sequence of pitting; perhaps slight accidental damage to one surface resulted in abnormally high local stresses at these particular points.

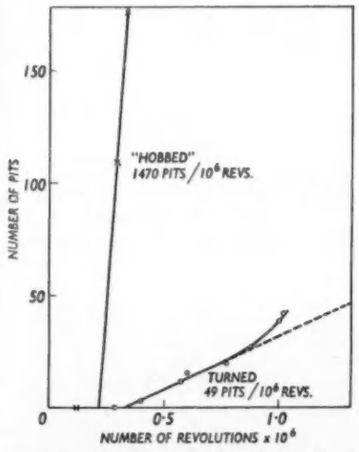

Fig. 12—Comparison of hobbed and turned surfaces

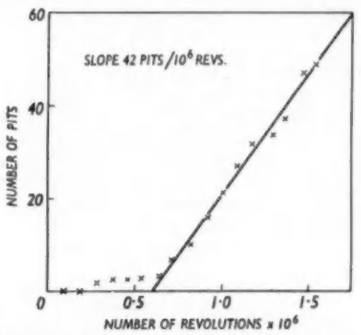

Fig. 13—Graph showing number of pits at intervals during an experiment

Having observed that gear tooth contact cycles can be far more frequent than asperity stress cycles, it became obvious that it would be interesting to follow the number of pits versus asperity stress cycles graph to larger numbers of cycles. If pits are caused by stresses in excess of the fatigue limit then, when a certain number of stress cycles have been reached, all asperity contacts having stresses sufficiently high to cause failure should have produced pits, and no further pitting should ensue since all other stresses would be below the fatigue limit of the material (Fig. 14). This is, of course, provided that the amount of surface lost by pitting is insufficient to cause an appreciable increase in the loading on other asperities. Fig. 15 shows the results from some gears in a 5in centres back to back test rig. At about 3×10^5 asperity stress cycles the number of pits tends to remain constant, though the number on each gear is very different. The fluctuation in numbers of pits on a particular gear is due to the fact that all pits visible to the naked eye were counted and slight changes in illumination could result in some of the tiniest pits not being noticed.

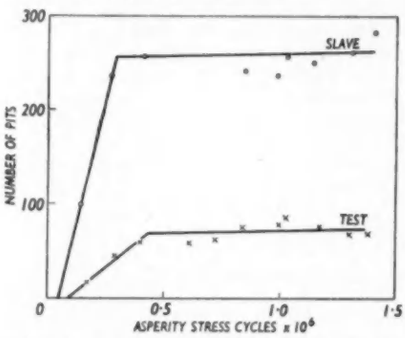

Fig. 15—Number of pits on gearwheel teeth

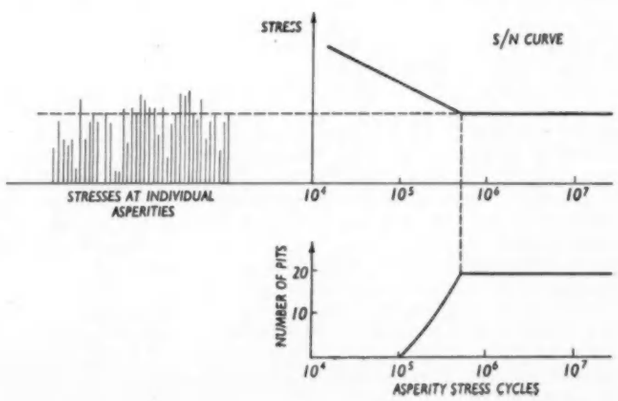

Fig. 14—Diagram to illustrate the relationship between the *S/N* curve and the number of pits/number of cycles graph

Technical Contributors Section (*Continued*)

In this particular experiment the load was not much in excess of the known maximum load for these materials. Under such conditions the size and numbers of pits are quite small, but as the percentage overloading increases so both the size of pits and their number increase.

This behaviour observed on laboratory test specimens is consistant with the phenomenon known on gears as "initial pitting." In this, pitting may start during the early life of the gears, but after a certain period of running ceases to develop any further. When the damage continues to develop, the term "progressive pitting" is often used.

Conclusions

It has been shown that gear tooth pitting is similar to conventional fatigue both as regards the number of stress cycles before failure and also as regards the change of fatigue limit with the ultimate tensile strength of the material. These observations have enabled changes to be made in the Sykes expression relating the allowable load on helical gears to their life, which give better agreement with practical results. A simple relationship has been suggested which would probably be satisfactory for the majority of involute gears, namely

$$\text{Fatigue Factor} = \frac{K}{(\text{u.t.s.})^2} = 0{\cdot}06.$$

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Stage-Wise Evaporation in Boilers in the Soviet Union

By J. JACKSON

In stage-wise evaporation, the boiler system is divided up into two or more distinct sections, the blow-down from the first section constituting the feed-water to the second section, the blow-down from which in turn becomes the feed-water to the third section and so on. This arrangement has a number of advantages.

Contamination of the steam, as a result of carry-over of droplets of boiler-water, leads to objectionable deposit formation in superheaters and on turbine blades and depends, among other things, on the dissolved solids content of the boiler-water; for a given boiler design and operating conditions, in fact, there appears to be a limiting dissolved solids content above which serious steam contamination occurs. Stage-wise evaporation makes it possible, even with high concentrations of dissolved solids in the feed-water, to keep the dissolved solids content in the primary section below the limiting value, yet without the excessively large blow-down, and hence excessive heat losses, that would otherwise be necessary. The steam from the primary section is thus of adequate purity. In addition, the system is so arranged that the bulk of the steam generated by the boiler (about 70 to 80 per cent of the total) comes from this primary section. Steam from the remaining sections, where the water contains much higher salt concentrations, thus has comparatively little effect on the overall purity; if necessary it can be returned to the primary section, and its purity increased there by washing with the incoming feed-water. Thus, stage-wise evaporation makes possible the generation of steam of the necessary purity from more highly impure feed-water than would otherwise be possible; it conserves blow-down and thus gives improved heat economy; and finally, by making water of poorer quality acceptable, it reduces water-treatment costs.

The application of the principle of stage-wise evaporation is most widely known in this country in the form of the Foster Wheeler dual-circulation steam generator.[1] In this type of boiler, it is common practice for the two sections into which it is divided to be located in two separate drums, as shown diagrammatically in Fig. 1. Here, as shown in Fig. 1, the water-wall tubes, with their high rates of heat transfer, constitute the primary section, and the lower rated boiler tubes the secondary section. In addition, it is also possible for both primary and secondary sections to be located in a single drum. The first dual-circulation boiler was installed in the U.S.A. in 1948; units of this type were installed recently by the C.E.G.B. at its power station in Spondon.

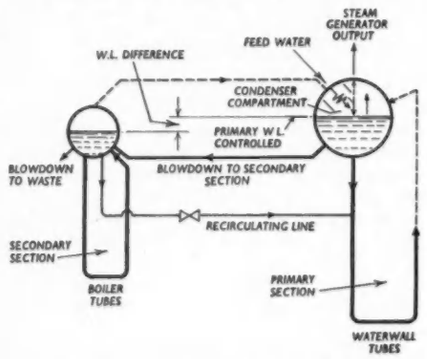


Fig. 1—Dual-circulation boiler (from Foster Wheeler bulletin B-50-11, 1950)

Stage-wise evaporation has also been widely used in boilers in the Soviet Union, where, it is claimed, the principle was discovered by the Soviet engineer Romm in 1938.[2] While the dual-circulation boiler is of course well known, less is known about the Soviet developments, so that some account of them may be of interest.

In Russian terminology, the primary section is known as the "pure" section, while the other sections are known as "salt" sections; these salt sections can be either internal or external, i.e. inside or outside the drum, and if external, take the form of cyclones. The use of a separate drum for a salt section seems to be unknown, and the following types of stage-wise evaporation system are used,[3] as shown in Fig. 2:

(1) With a second stage inside the drum.
(2) With an external second stage.
(3) With an internal second stage and an external third stage.

The internal salt sections correspond closely to the Foster Wheeler dual-circulation system with the sections located inside the drum. They are said to be inexpensive to install, but to suffer from the disadvantage that back-flow of boiler-water takes place from the salt to the pure section as a result of leakage, thus increasing the salt concentration in the pure section and reducing its effectiveness; troughs or collecting chambers can be fitted to reduce this back-flow (Fig. 3).

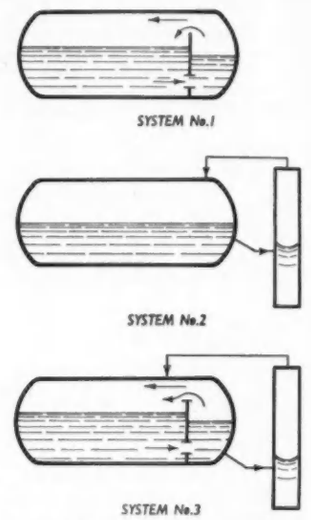


Fig. 2—Stage-wise evaporation systems

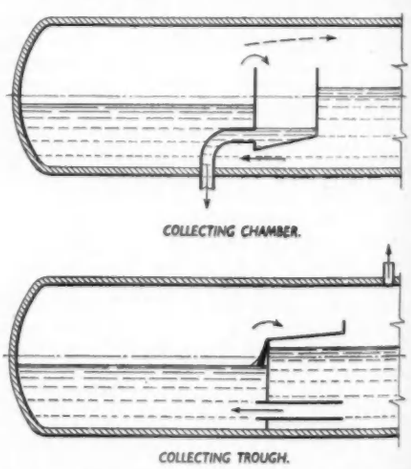


Fig. 3—Devices for collecting reverse flow of boiler-water from salt sections

The external cyclones seem to be purely a Soviet development, and therefore deserve greater attention. Cyclones inside the drum are, of course, widely used in this country for separating the steam/water mixture as it emerges from the boiler tubes, prior to

removal of entrained droplets by means of scrubbers. The external cyclones, it appears, combine this function of separating the steam/water mixture with that of acting as a salt section in stage-wise evaporation. The various ways in which external cyclones can be arranged are shown in Fig. 4, while

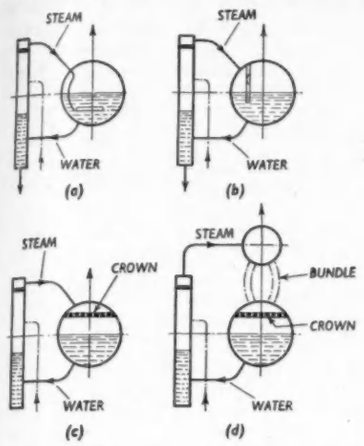


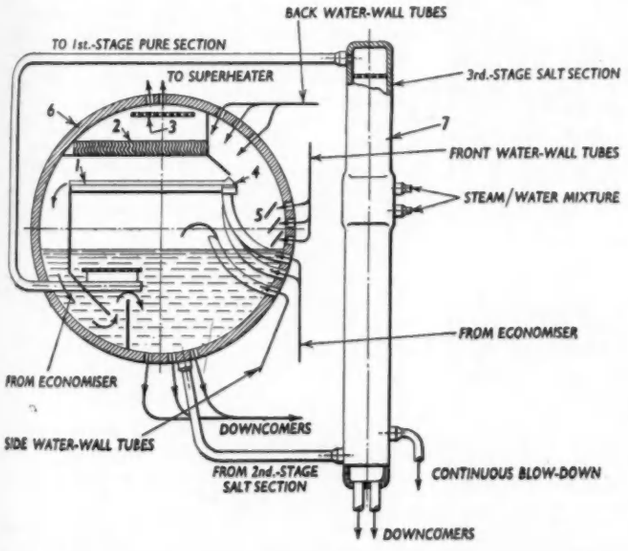
Fig. 4—Systems for arrangement of external cyclones

a more detailed view of System 4 (*a*) is shown in Fig. 5; it is clear that in this system the incoming steam from the external cyclone is washed by the boiler-water of the pure section, so that its purity will be increased. A detailed drawing of the type of cyclone shown in Fig. 5 is given in Fig. 6.[4]

The main advantage of using external cyclones is said to be that back-flow from the salt to the pure section is then impossible, thus making it possible to use higher salt concentrations in the boiler-water in them; it is said, in fact, that the salt concentration in external cyclones can be greater by a factor of 1½ to 2 than that for salt sections inside the drum, and as large as 6000 p.p.m.[4] The disadvantage of external cyclones is said to be their high cost,[5] particularly where they are introduced when a boiler is being reconstructed. There seems to be some doubt about this, however, for it has been stated more recently that they are not difficult to construct, and that they can be made at the workshops of the plant with which the boiler unit is associated.[5] It is said that they consist of an ordinary tube of length 3000mm to 4000mm and diameter 200mm to 300mm, and that they permit the increase of the salt content of the blow-down to 6000 to 8000 p.p.m., as compared with 1500 to 3000 p.p.m. for boilers without stage-wise evaporation.

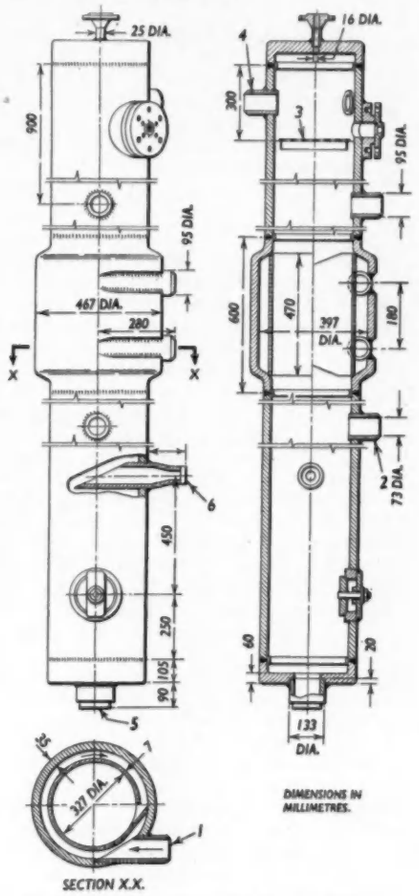
It has already been mentioned that the use of stage-wise evaporation should enable poorer quality water to be used in the boiler, and thus to reduce water-treatment costs; if water of distilled quality is not necessary, for example, the costly process of demineralisation will not be needed, and some less thorough, and cheaper, method can be used. Thus Kostrikin[6] has reviewed the whole question of methods of avoiding the need for using demineralisation in boiler feed-water treatment, including stage-wise evaporation, but unfortunately in a journal which is semi-popular in character, so that his article leaves much that is unexplained, and contains no references which would make it possible to obtain further information. Kostrikin divides all thermal power stations into two classes; (1) those where the total steam losses do not exceed the output of which "gas evaporators" (the nature of which is not explained) are capable, and (2) those where these losses cannot be made good by the output of gas evaporators. For power stations of the second type fitted with drum-type boilers operating at pressures not greater than 160 atmospheres (2400 lb per square inch) Kostrikin says that, by using stage-wise evaporation together with steam washing, it should be possible to use feed-water containing up to 0·5 p.p.m. of silica and up to 20 to 30 p.p.m. of dissolved solids, and that consequently the treatment of this feed-water can be effected by ordinary methods and without demineralisation. According to Kostrikin, the field of application of demineralisation should be extremely small, other methods of ensuring steam purity, such as stage-wise evaporation, being just as reliable and far cheaper.

It has not proved possible to discover with complete certainty the extent to which Kostrikin's views have been adopted in the Soviet Union with the consequent replacement of demineralisation by other, cheaper methods. Some indication of the position, is, however, given in the paper by Kvyatkovskii and Zhivilova,[7] who are concerned with the magnesia method of silica removal; this, of course, is the cheap, alternative method of removing silica, as compared with the use of ion-exchange resins. Silica removal is a vital part of boiler feed-water treatment because silica is one of the impurities in the steam produced by boilers, and of particular importance in that silica deposits on turbine blades are difficult to remove. According to these authors, the magnesia method of silica removal is the most important in the Soviet Union, and up to 1957 numerous installations for operating this process had been constructed. They envisage that in the future, drum-type boilers operating at pressures of up to 140 atmospheres (2100 lb per square inch) would become widely used, and that the feed-water for such boilers should contain not more than 0·3 to 0·5 p.p.m. of silica (calculated as SiO_2); the magnesia method would be capable of producing water of this quality where 50 to 70 per cent of returned condensate was available, i.e. in the overwhelming majority of cases. It does appear, therefore, that it is the intention, in the Soviet Union, to avoid the need for demineralisation wherever possible, whether by the use of stage-wise evaporation, or by other means.



1—Washing device.
2—Venetian-blind separator.
3—Perforated plate.
4—Feed trough.
5—Baffle plates.
6—Drum.
7—External cyclone.

Fig. 5—Detailed view of system (*a*) of Fig. 4



1—Connection for introduction of steam/water mixture.
2—Connection for instrument for measuring water level.
3—Perforated plate.
4—Connection for steam withdrawal tube.
5—Downcomer.
6—Connection for continuous blow-down.

Fig. 6—Detailed view of external cyclone

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Technical Contributors Section (*Continued*)

Mechanical Shock and its Measurements

By L. B. W. JOLLEY, M.A.(Cantab.), M.I.E.E.*

The resistance of mechanical systems to withstand shock or impact has been a problem for a long time. Unfortunately some methods of obtaining a measure of shock are open to grave suspicions; and in this article one method (not the only one by any means) is described: a vibratory reed is used and its deflection is measured under impulsive conditions. To check that this method is sound, Hertz' theory of impact is used experimentally and a good agreement is found between theory and experiment. This led to a further series of tests on vibrating reeds and the results are discussed.

SOME years ago it was desired to ascertain the effect of an impulsive blow on certain classes of apparatus and instruments. A common method then employed was to attach such apparatus to a plate which could be subjected to a blow. The "magnitude" of the blow was measured by observing the plastic compression of a copper pellet, similar pellets having been previously tested under conditions of violent acceleration, and their deformation measured for various "numbers of g." The apparatus was then stated to be able to withstand so many g.

The indiscriminate use of an acceleration measurement of this kind seemed to many people to be unwarranted. The mechanical damage done by a blow depends on the stresses produced in the body exposed to it; and preliminary investigation of the effect of a longitudinal blow on an elastic rod showed the stresses to be proportional, in many cases, to the applied impulse (force × time) and not to the resulting acceleration of the rod. In general, the effect of a blow may be expected to be quite different from the effect of testing a body on, for example, a whirling arm or a centrifuge, where the centrifugal force rises relatively slowly to its ultimate value, and the "number of g" is likely to be a measure of the stresses produced during the test; and, conversely, a test (such as in a centrifuge) for which "number of g" is a measure of the stress in the test object, is not necessarily a guide to the resistance of the test body to shocks. The consideration of the behaviour of the rod suggested that where the duration of an impulse was not long in comparison with the time needed for the dominant form of elastic distortion to propagate itself through the body experiencing that impulse, the main stresses in the body would be proportional to the change in velocity experienced by the body.

A similar investigation into the motion of a freely vibrating cantilever clamped to a suitable base which was subject to an impulsive blow gave similar results. This not only gave weight to the view that in measuring shock it is wrong to treat "number of g" indiscriminately as a measure of the shock, since the impulse would in many cases be a more appropriate measure; but it also suggested that a suitable impulse-measuring instrument might be one which recorded the deflection of a cantilever reed subjected to the shock. Instruments of this type were constructed, and were calibrated on a double-pendulum machine in which the hammer pendulum was allowed to strike a pendulous anvil carrying the instrument. In the calibration process, Hertz's theory of impact of elastic bodies was used when considering the behaviour of the pendulum machine, and checked by measuring the area of contact between hammer and anvil—a very close agreement between theory and observation being found.

Within the range for which the measuring instrument was originally intended to be used, the agreement between the calculated and the observed reed deflections was sufficiently satisfactory, though some unexplained anomalous results were obtained. Unfortunately, the work was carried out during wartime, and fuller investigation was not possible. The results obtained suggest, however, that with further work these anomalies in behaviour should be curable.

The theoretical discussion, though limited to the behaviour of a cantilever, is sufficient to establish the point that, in considering the effect of mechanical shock, "number of g" can be a wholly misleading "measure" of shock. Many forms of equipment that are exposed to shocks during use consist (in effect) of assemblies of rods and beams, and for such assemblies the measurement of the impulse which they will withstand is likely to provide a better "simple" measure of their resistance to shocks than would a measure based on the accelerations to which they are exposed. Similar considerations will apply to other cases in which failure results from a "general" propagation of distortion through a structure, as distinct from cases in which failure results from localised stress concentrations produced by local application of the forces causing the shock. For example, a cup dropped on an earthenware sink may break (when it would not do so on a wooden sink) because the local stress concentrations at the point of impact with the earthenware sink are so high as to start cracks which then propagate through the cup along with the wave of distortion; and the vulnerability of the cup in these two cases is not properly measured either by "number of g" or the total impulse it suffers. But reasonable consideration of the type of failure produced in a body exposed to shocks will generally show whether "impulse" is a sensible indication of shock intensity in relation to that body—and will also show that "number of g" frequently is not.

The literature on the subject is extensive; but no lengthy bibliography is included, and the references given are mainly to relatively early work as being less likely to be familiar. Considerable work has been done in America in recent years on the impact of weights on beams and plates, and the detailed techniques (of analysis and experiment) are valuable; but the work does not appear to have been directed as here to the question of a reasonable and fairly general "measure" of the severity of the shocks to which a body is exposed.

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Collision of Elastic Bodies

Love in *Mathematical Theory of Elasticity*, Fourth Edition, page 193, describes Hertz's theory for the displacement of two bodies pressed together. It is there remarked: "Let two bodies be pressed together so that the resultant pressure between them is P. The parts of the bodies near the points of contact will be compressed, so that there is contact over a small area of the surface of each . . . We propose to determine the curve of compression and the distribution of pressure over the compressed area." Hertz accomplishes this for two ellipsoids in contact, and proceeds to apply the results to the problem of the impact of two solid bodies.

Love goes on to say: "The ordinary theory of impact, propounded by Newton, divides bodies into two classes, perfectly elastic and imperfectly elastic. In the former case, there is no loss of kinetic energy in impact. In the latter case, energy is dissipated on impact. Many actual bodies are not very far from being perfectly elastic in the Newtonian sense. Hertz's theory of impact takes no account of the dissipation of energy; the compression at the place of contact is regarded as gradually produced, and as subsiding completely by reversal of the process by which it is produced. The local compression is then regarded as a statical effect. In order that such a theory may hold, it is necessary that the duration of the impact should be a large multiple of the gravest period of free vibration of either body which involves compression at the place in question."

Further, Rayleigh has shown that in bodies on impact, the energy of the vibration is very small compared with the energy before collision; and Banerji has added an interesting note to the general theory by showing that the sound emitted by the collision of elastic bodies is due to aerial waves set up by the reversal of the direction of the bodies as a whole, and not to elastic vibration in the bodies themselves. Finally, Raman has obtained experimentally a relation between the velocity of impact and the coefficient of

Symbols

a—Area of cross section of reed in square feet.
a_t—Radius of contact area at any time t of Hertz spheres in feet.
m—Mass of falling hammer in pounds.
m'—Mass of anvil in pounds.
p_n—Periodicity of reed.
r and r'—Radii of spheres in Hertz theory.
t—Any instant of time in deflection of reed and during compression of spheres.
v_0—Velocity of m at instant of striking m' in feet per second.
v_1—Velocity of m at instant of cessation of impact in feet per second.
v_0'—Velocity of m' at instant of impact in feet per second.
v_1'—Velocity of m' after impact in feet per second.
v—Velocity of m at any instant during compression.
v'—Velocity of m' at any instant during compression.
w—Weight per unit length of reed in pounds per foot.
y_m—Maximum deflection of any point of reed at distance x.
A—Peak acceleration of shock curve in ft/sec^2.
E—Modulus of elasticity of reed and falling sphere m in lb/ft^2.
E'—Ditto of m'.
I—Flexural moment of inertia of reed in ft^4 units; and moment of inertia of pendulum m in lb ft^2 about axis of rotation.
I'—Moment of inertia of pendulum m' about axis of rotation in lb ft^2.
I_W—Moment of inertia of bob weight W about axis perpendicular to the plane of paper in lb ft^2.
K_W—Radius of gyration of bob weight in feet.
T—Total time of impact in seconds.

restitution ; and he shows that at low velocities the coefficient is in most cases of the order of unity for certain materials. He also shows how the coefficient may be calculated. The above references are to articles which are of academic interest.

The assumptions on which the calculations (which follow) depend are that the bodies are perfectly elastic ; and that no energy is absorbed during impact, but that it is wholly recoverable in recoil velocities.

Love states : "The quantity α_t is the relative displacement of the centre of mass of the two bodies, estimated from their relative position at the instant when the impact commences, and resolved in the direction of their common normal. The pressure P between the bodies is the rate of destruction of the momentum of either."

With the above in mind, the following equations have been derived :

$$\frac{d}{dt}\left(\frac{mm'\dot{\alpha}_t}{m+m'}\right) = -P \quad . \quad . \quad . \quad (1)$$

where m and m' are the masses of the bodies.

From previous equations (Love, page 197) relating to the static state

$$P = k_2\,\alpha_t^{3/2} \quad . \quad . \quad . \quad . \quad . \quad (2)$$

In these two results, if the bodies are spheres of radii r and r' and where

$$\theta = \frac{1-\sigma^2}{\pi E g} \text{ and } \theta' = \frac{1-\sigma'^2}{\pi E' g}$$

then

$$k_2 = \frac{4}{3\pi}\left(\frac{r\,r'}{r+r'}\right)^{1/2}\frac{1}{\theta+\theta'}$$

and if

$$k_1 = \frac{m+m'}{m\,m'}$$

$$\ddot{\alpha}_t = -k_1 k_2\,\alpha_t^{3/2} \quad . \quad . \quad . \quad . \quad . \quad (3)$$

This equation may be integrated to the form—

$$\frac{1}{2}(\dot{\alpha}_t^2 - v_0^2) = -\frac{2}{5}k_1 k_2 \alpha_t^{5/2} \quad . \quad . \quad (4)$$

where v_0 is the initial value of $\dot{\alpha}_t$, i.e. velocity of the approach of the bodies before impact ; the value of α_t at the instant of greatest compression, i.e. when $\dot{\alpha}_t = 0$ is

$$\alpha_m = \left(\frac{5v_0^2}{4k_1k_2}\right)^{2/5} \quad . \quad . \quad . \quad . \quad (5)$$

It is not possible to integrate (4) directly, but T the total time of compression is given by

$$T = 2\int_0^{\alpha_m}\frac{d\alpha_t}{\left\{v_0^2 - \frac{4}{5}k_1k_2\alpha_t^{5/2}\right\}^{\frac{1}{2}}} = \frac{2\alpha_m}{v_0}\int_0^1 \frac{dx}{\{1-x^{5/2}\}^{\frac{1}{2}}}$$

$$= \frac{4}{5}\sqrt{\pi}\frac{\alpha_m}{v_0}\frac{\Gamma^{(2/5)}}{\Gamma^{(9/10)}} = \frac{2\cdot 9432\,\alpha_m}{v_0} \quad . \quad . \quad (6)$$

The area of contact of the spheres at any moment is equal to πa_t^2 in which Love shows that

$$a_t = \left(\frac{\alpha_t r r'}{r+r'}\right)^{\frac{1}{2}}$$

and therefore the radius of maximum contact area is

$$a_m = \left(\frac{\alpha_m r r'}{r+r'}\right)^{\frac{1}{2}} \quad . \quad . \quad . \quad . \quad . \quad (7)$$

and

$$\alpha_m = \left[\frac{15\pi v_0^2(\theta+\theta')mm'}{16(m+m')}\right]^{2/5}\left(\frac{r+r'}{rr'}\right)^{1/5} \quad . \quad (8)$$

If a sphere of radius r strikes a flat plate, it would then be necessary to put $r' = \infty$, and in principle, this would not be valid unless the plate were of infinite size ; there is no way out of this difficulty except by accepting the above assumption, and therefore, in the case of a sphere of radius r striking a flat plate, a_t is taken to be

$$a_t = \sqrt{\alpha_t r} \text{ and } a_m = \sqrt{\alpha_m r} \quad . \quad . \quad . \quad . \quad (9)$$

and

$$a_m = \left[\frac{15v_0^2 mm'(1-\sigma^2)}{8E(m+m')g}\right]^{2/5} \times \frac{1}{r^{1/5}} \quad (10)$$

assuming the plate and the sphere have the same elastic constants.

The maximum force between the bodies is given by

$$P = \frac{4a_m\alpha_m}{3\pi(\theta+\theta')} \quad . \quad . \quad . \quad . \quad (11)$$

and the pressure at any radius β of the area of contact by

$$P' = \frac{3P}{2\pi a_m^2}\sqrt{1-\frac{\beta^2}{a_m^2}} \quad . \quad . \quad . \quad (12)$$

and the maximum pressure is when

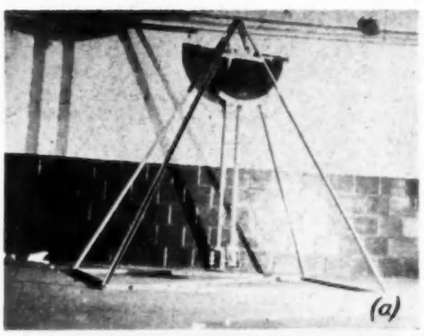
$$\beta = 0 \text{ or when } P' = \frac{3P}{2\pi a_m^2}$$

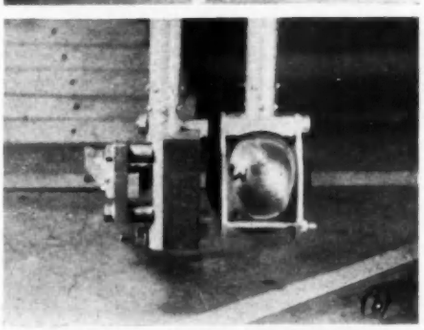
These equations are used later where the design of an instrument is considered for applying shocks to apparatus and to the calibration of an impactometer.

Design of New Shock Testing Machine

This new machine is illustrated in Fig. 1 (*a*), (*b*) and (*c*).

In Fig. 1(*a*) the complete machine is shown, and consists of a framework supporting two rods, one holding the hammer (a sphere), and the other the anvil (a flat plate). The rods pivot on ball bearings situated a distance apart, so that when the hammer and anvil are stationary they are just in contact.





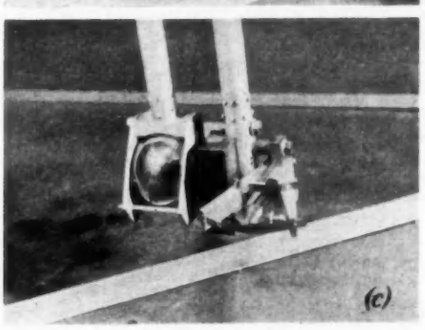


Fig. 1

This ensures that when the hammer strikes the anvil, the movement of the hammer is horizontal. Both of their angular movements can be determined by a large protractor. Both hammer and anvil are carried in cradles attached to the rods.

The main particulars of this construction are :

Distance from support of rods to the point of contact R	$R = 6$ft
The rods supporting the hammer and anvil were made of steel tubing 1·790in in diameter and of wall thickness 33 mil, and weight per unit length ...	0·62341 lb per foot
Radius of sphere	$r = 3$in

Particular attention was paid to the material from which the sphere and plate were made. It was of great importance that after impact there should be no permanent deformation of the surfaces, as this would detract from the accuracy of measurement of the contact area.

The only steel which complied with these conditions was J_3 of William Jessop and Sons, Ltd. (cast Z6021), a high-speed tool steel which had the following composition : Carbon, 0·62 ; Manganese, 0·34 ; Silicon, 0·31 ; Sulphur, 0·019 ; Phosphorus, 0·015 ; Chromium, 4·30 ; Tungsten, 17·70 ; Vanadium, 1·42.

The heat-treatment was : cooled in air from 1250 deg. Cent.; double tempered at 550 deg. Cent.; and the hardness after treatment was DH/30 860.

The elastic constants were :

Young's modulus	$32{\cdot}1 \pm 0{\cdot}5 \times 10^6$ lb/in^2
Shear modulus	$12{\cdot}7 \pm 0{\cdot}2 \times 10^6$ lb/in^2
Poisson's ratio	$0{\cdot}26 \pm 0{\cdot}025$

In the present theory of the shock testing machine, account is taken of the mass of the rotating arms and the corrections resulting therefrom ; then it can be shown that if $v_0' = 0$

$$v_1' = \frac{2I}{I+I'}\,v_0 \text{ (later called } \mu) \quad . \quad . \quad (13)$$

and

$$v_1 = \frac{I+I'}{I+I'}\,v_0 \quad . \quad . \quad . \quad . \quad . \quad (14)$$

Hence, a modification can be made to the Hertzian theory of impact. Thus, if after the instant of impact the mass centre of m has travelled a distance of α in the direction of increasing compression of the interface, and the mass centre of m' has travelled a distance of α' (also in the direction of increasing compression), the total compression α_t will be (on Hertz's assumption)

$$\alpha_t = \alpha + \alpha'$$

and

$$-I\frac{d^2\alpha}{dt^2} = -\frac{I\,I'}{I+I'}\,\frac{d^2\alpha_t}{dt^2} = PR^2 \quad . \quad (15)$$

Equation (15) is equivalent to Equation (1) if

$$\frac{R^2(I+I')}{I\,I'} \text{ is written for } \frac{m\,m'}{m+m'}$$

Accordingly the new equations for the two pendulums correspond with Equation (3) provided that

$$k_3 = \frac{R^2(I+I')}{I\,I'} \text{ is substituted for } k_1.$$

Thus

$$\alpha_m = \left(\frac{5\,v_0^2}{4k_2k_3}\right)^{2/5} \quad . \quad . \quad . \quad . \quad (16)$$

where

$$k_2 = \frac{2Eg\sqrt{r}}{3(1-\sigma^2)}$$

(and has dimensions $M\,L^{-1/2}T^{-2}$) . (17)

The velocity v_0 with which the hammer strikes the anvil is obtained from the relations.

$$mgh(1-\cos\phi_0) = \frac{1}{2}I\omega^2 = \frac{1}{2}Iv_0^2/R^2$$

Technical Contributors Section (*Continued*)

where ϕ_0 is the angular fall of the hammer. or

$$v_0 = 2\sqrt{\frac{mghR^2}{I}} \sin\frac{\phi_0}{2}$$

$$= \frac{2\pi R}{\tau_p} \sin\frac{\phi_0}{2} \quad . \quad . \quad . \quad . \quad (18)$$

where τ_p is the " half-time " (i.e. the time of the single swing to or fro) of the pendulum formed by the hammer and the supporting arm, namely

$$\tau_p = \pi\sqrt{\frac{K^2}{hg}}$$

It was considered that if measurements were made of the velocity of impact of m (namely v_0) of the hammer and of the rebound of the anvil v_1', and of the maximum contact area during impact (diameter d or radius a_m) between the sphere and plate, a check might be obtained of the use of Hertz's theory as a calibrating device. It was found, however, that there was a certain tendency for the pendulum to twist on impact, and it was important that this should not occur, and certain modifications were necessary to the original design.

A further detraction from accuracy was noted during the initial tests ; and this was caused by the vibration of the steel tubes carrying the sphere and plate during impact. This would result in a modification to the values of the moments of inertia of the pendulous system. The " modified " moments (I_{mod} and I'_{mod}) were therefore used in the calculations.

Two series of tests were conducted for the calibration : the first was to check the apparatus itself for compliance with Hertz's theory, and the second was to test the impactometer. In both series the hammer (sphere) remained the same ; but in the case of the anvil, certain changes were made between the two tests. The unaccented symbols used below refer to the hammer in all tests, and the " dash " sign to the anvil for the tests on the calibrator, and the " double dash " sign for the tests on the impactometer. The following table then gives the various values used in all cases.

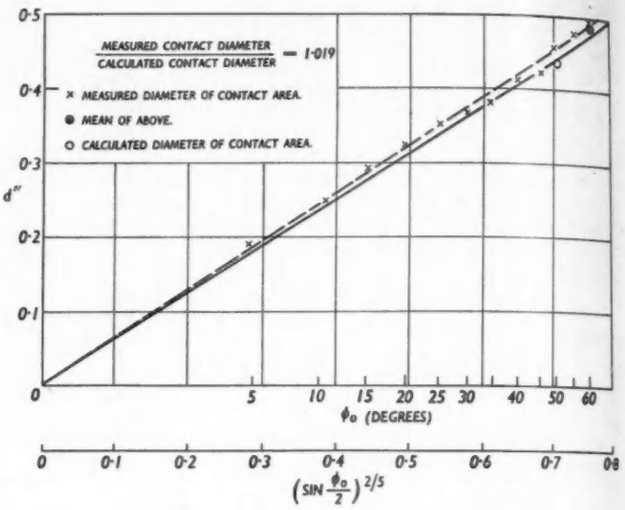

MEASURED CONTACT DIAMETER / CALCULATED CONTACT DIAMETER = 1·019
× MEASURED DIAMETER OF CONTACT AREA.
● MEAN OF ABOVE.
○ CALCULATED DIAMETER OF CONTACT AREA.
d''
φ0 (DEGREES)
(SIN φ0/2)^2/5

Fig. 2—Hertz Spheres. Calculated and measured contact area (diameter)

With elastic constants provided by Wm. Jessop for J3 steel.

Tests on impactometer

$$k_3 = \frac{R^2(I_{mod}+I''_{mod})}{I_{mod}\times I''_{mod}} = 5\cdot6708\times10^{-2}$$

$$\frac{2\,I_{mod}}{I_{mod}+I''_{mod}} = 1\cdot1371$$

and in both cases

$$k_2 = \frac{4}{3\pi}\,\frac{\sqrt{r}}{\theta+\theta'} \text{ where } \theta=\theta'=\frac{1-\sigma^2}{\pi E g}\,(r=3\text{in})$$

$$= 5\cdot3211\times10^{10} \text{ (ft sec units).}$$

The four equations required for determining the calibration are :

$$\frac{d}{2} = a_m = \sqrt{\alpha_m r} \qquad \text{(Equation (9))}$$

$$v_0 = \frac{2\pi R}{\tau_p}\sin\frac{\phi_0}{2} \qquad \text{(Equation (18))}$$

$$\alpha_m = \left(\frac{5v_0^2}{4\,k_2k_3}\right)^{2/5} \qquad \text{(Equation (16))}$$

$$v_1' = \frac{2\,I_{mod}v_0}{I_{mod}+I'_{mod}} \qquad \text{(Equation (13))}$$

From these equations the diameter of the contact area

$$d = 2\sqrt{r}\left(\frac{5}{4k_2k_3}\right)^{1/5}\left(\frac{2\pi R}{\tau_p}\right)^{2/5}\left(\sin\frac{\phi_0}{2}\right)^{2/5} \text{ ft}$$

$$. \quad . \quad . \quad . \quad . \quad (19)$$

and from the values given above

$$d' \text{ (in)} = 6\cdot141\times10^{-1}\left(\sin\frac{\phi_0}{2}\right)^{2/5}$$

with the " dash " sign for test on the calibrator and

$$d'' \text{ (in)} = 6\cdot0409\times10^{-1}\left(\sin\frac{\phi_0}{2}\right)^{2/5}$$

with the " double dash " signs for the test with the impactometer.

The diameter of the contact area was measured by inserting a thin piece of paper between the hammer and anvil during impact. When great care was taken with the tests, the bruised area was very nicely circular, and it was easy to measure its diameter reasonably accurately. Further, it is seen from Equation (19) that if this diameter is plotted against $\left(\sin\frac{\phi_0}{2}\right)^{2/5}$ a linear relation should result.

Thus a plot of Equation (19) should show the correlation between theory and experiment, and the result is given in Fig. 2. The points X show the results of measuring the diameter of the bruised areas for various values of ϕ_0 and the dotted line represents the " zero sum " of their readings, whereas the full line is that calculated from Equation (19).

Considering the devious channels through which the theory led, the agreement is surprisingly good (error of 1·9 per cent) and this provided sufficient impetus for a pursuance of the application of these principles to impactometer designs.

In the calibration of the impactometer itself, Equation (18) is used, namely

$$v_0 = \frac{2\pi R}{\tau_p}\sin\frac{\phi_0}{2} = 27\cdot946\sin\frac{\phi_0}{2}$$

and Equation (13)

$$v_1' = \frac{2I_{mod}v_0}{I_{mod}+I''_{mod}} = 1\cdot1371\ v_0$$

substituting I_{mod} and I''_{mod} for I and I'' and therefore

$$v_1' = 31\cdot777\sin\frac{\phi_0}{2} \quad . \quad . \quad . \quad . \quad . \quad (20)$$

The calculated behaviour of the two masses m and m' during contact is shown in Fig. 3 which depicts the relation between

$$\frac{d^2\alpha_t}{dt^2} \text{ and } \alpha_t;$$

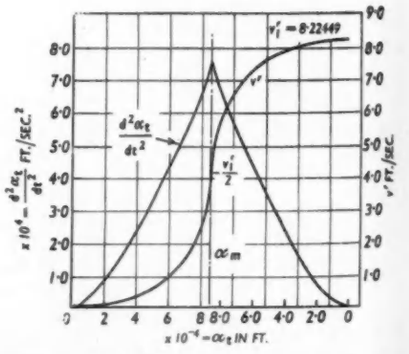


Fig. 3—Curve of $\frac{d^2\alpha t}{dt^2}$ and v^1 with αt for $\phi_0 = 30$ deg. $v_0 = 7\cdot22270$ft/second ; $v_1^1 = 8\cdot22449$ft per second ; $\alpha m = 8\cdot59695\times10^{-4}$ft. Time of impact $T = 3\cdot5\times10^{-4}$ seconds

TABLE

	h, ft	τ_p, seconds	K^2 ft²	m lb	I	I_{mod}	
Hammer...	5·1198	1·3490	30·397	49·546	1506·05	1471·44	
Anvil (')	5·01014	1·3478	29·695	44·765	1329·28	1294·67	Tests on Hertz calibrator
Anvil (")	4·8645	1·3600	29·353	39·218	1151·17	1116·56	Tests on impactometer

The radius of gyration in each case was determined from the time of oscillation of the pendulum about the axis of rotation, and this, with the distance h, h' or h'' of the centre of gravity from the axes of rotation gives the radius of gyration about the axes of rotation from the equation

$$K^2 = \frac{\tau_p^2\,hg}{\pi^2}$$

The values of h, h' and h'' were measured by supporting the pendulums on a knife-edge, and the values of τ_p, τ_p' and τ_p'' by timing 500 swings with a stop-watch.

From the above data

Tests on calibrator

$$k_3 = \frac{R^2(I_{mod}+I'_{mod})}{I_{mod}\times I'_{mod}} = 5\cdot2272\times10^{-2}(R=6\text{ft})$$

(Dimensions M^{-1})

$$\frac{2I_{mod}}{I_{mod}+I'_{mod}} = 1\cdot0639$$

and also between v' and a_t for a value of ϕ_n=30 deg. It will be seen that the velocity of the anvil carrying the impactometer rises from zero to one-half its full value when $a_t=a_m$ and to its full value when a_t is again zero; and this velocity namely 8·22449ft per second is the administered shock to the impactometer.

Effect of Shock on a Flexible Reed

Consider the motion of a uniform cantilever of length l built in at the root, and bearing a load W at the free end.

Let it be supposed that an arbitrary motion be imposed on one end in the direction of the y axis, the displacement u_0 on this end being a function of time given by

$$u_0=f(t)$$

and let it further be supposed that the deflection at any point of the cantilever distant x from the root is y: the axes xoy moving parallel to the y axis in such a manner as always to pass through the root of the cantilever.

The total displacement of any point of the cantilever at any instant is u_o+y; and the equation of motion (on the ordinary Bernoulli-Euler theory) is given by

$$EI\frac{\partial^4 y}{\partial x^4}=-\frac{\rho a}{g}\frac{\partial^2}{\partial t^2}(y+u_0) \quad . \quad . \quad . \quad (21)$$

Let $\xi=\frac{x}{l}$ then (21) becomes

$$\frac{\partial^4 y}{\partial \xi^4}=-\frac{\rho a l^4}{gEI}\frac{\partial}{\partial t^2}(y+u_0) \quad . \quad . \quad (22)$$

It is usual in problems of this kind to assume that the solution is of the form

$$y=\sum_1^\infty u_n(\xi)\,T_n(t) \quad . \quad . \quad . \quad . \quad (23)$$

where u_n is a function of ξ only and T_n a function of t only; and this form of solution is assumed in the method here adopted; the functions used to serve as u_n being here chosen as the characteristic functions for the solution of the associated equation

$$\left.\begin{aligned}&\frac{\partial^4 U}{\partial \xi^4}=-\frac{\rho a l^4}{gEI}\frac{\partial^2 U}{\partial t^2}\\ &\text{with the terminal conditions at}\\ &\xi=0, U=\frac{\partial U}{\partial \xi}=0\\ &\text{at}\\ &\xi=1, \frac{\partial^2 U}{\partial \xi^2}=-\frac{lI_W}{gEI}\frac{\partial^2 U}{\partial \xi \partial t^2}\\ &\text{and}\\ &\frac{\partial^3 U}{\partial \xi^3}=\frac{l^2 W}{gEI}\frac{\partial^2 U}{\partial t^2}\end{aligned}\right\} \quad (24)$$

that is to say, are functions such that

$$U=u\cos pt \quad . \quad . \quad . \quad . \quad . \quad (25)$$

satisfies Equation (24).

Before deriving the expressions for the functions T_n and showing that the resulting expression for y satisfies the terminal condition, it is convenient to derive the expressions for and to establish certain properties of the characteristic function u_n.

Substituting Equation (25) into (24)

$$\frac{\partial^4 u}{\partial \xi^4}=\frac{\rho a l^4}{gEI}p^2 u=\lambda^4 u \quad . \quad . \quad . \quad . \quad . \quad (26)$$

with the terminal conditions at

$$\xi=\partial, u=\frac{\partial u}{0\xi}=0$$

Whilst at $\xi=1$,

$$\frac{d^2 u}{d\xi^2}=\frac{lI_W}{gEI}p^2\frac{du}{d\xi}=\frac{I_W}{\rho a l^3}\lambda^4\frac{du}{d\xi}$$

or

$$\frac{d^2 u}{d\xi^2}=k_1\lambda^4\frac{du}{d\xi} \text{ where } k_1=\frac{I_W}{\rho a l^3}$$

and

$$\frac{d^3 u}{d\xi^3}=-\frac{l^3 W}{gEI}p^2 u=-\frac{W}{\rho a l}\lambda^4 u$$

or

$$\frac{d^3 u}{d\xi^3}=-k\lambda^4 u \text{ where } k=\frac{W}{\rho a l}$$

The general solution of (26) with the terminal conditions is

$$u=\cosh\lambda\xi-\cos\lambda\xi-K(\sinh\lambda\xi-\sin\lambda\xi) \quad . \quad . \quad (27)$$

Given the numerical values of k and k_1, it is possible to find the roots λ_n which are the characteristic numbers for the vibration problem.

It is further found that the value of K_n for any characteristic number λ_n is given by

$$K_n=\frac{(\sinh\lambda_n-\sin\lambda_n)+k\lambda_n(\cosh\lambda_n-\cos\lambda_n)}{(\cosh\lambda_n+\cos\lambda_n)+k\lambda_n(\sinh\lambda_n-\sin\lambda_n)} \quad . \quad . \quad . \quad . \quad . \quad (28)$$

and

$$k_1=\frac{1}{\lambda^3_n}\,\frac{\begin{array}{l}1+\cosh\lambda_n\cos\lambda_n\\ -k\lambda_n(\cosh\lambda_n\sin\lambda n-\sinh\lambda n\cos\lambda n)\end{array}}{\begin{array}{l}\cosh\lambda_n\sin\lambda_n\\ +\sinh\lambda_n\cos\lambda_n-k\lambda_n(1-\cosh\lambda_n\cos\lambda_n)\end{array}} \quad . \quad . \quad . \quad . \quad . \quad (29)$$

The above results are nothing more, of course, than the characteristic equation and numbers derived from the classical theory of a loaded cantilever.

Substitution of

$$y=\sum_{n=1} u_n(\xi)T_n(t)$$

in

$$EI\frac{\partial^4 y}{\partial\xi^5}+(\rho a l^4/g)\frac{\partial^2(y+u_0)}{\partial t^2}=0$$

gives

$$EI\sum_{n=1}\frac{d^4 u_n}{d\xi^4}T_n+(\rho a l^4/g)\sum_{n=1}u_n\frac{d^2 T_n}{dt^2}+(\rho a l^4/g)\frac{\partial^2 u_0}{\partial t^2}=0,$$

or, since

$$\frac{d^4 u_n}{d\xi^4}=\frac{\rho a l^4}{gEI}p_n^2 u_n,$$

and writing

$$\partial^2 u_0/\partial t^2=F(t),$$

then

$$(\rho a l^4)/g\sum_{n=1}\left[p_n^2 T_n+\frac{d^2 T_n}{dt^2}\right]u_n+(\rho a l^4/g)F(t)=0 \quad . \quad . \quad . \quad . \quad . \quad (30)$$

Now the term $-(\rho a l^4/g)\partial^2 y/\partial t^2$ represents the inertial force (per unit length) exerted on each element of the cantilever owing to that part of its acceleration which results from flexure, this force varying along the cantilever in dependence on ξ. Similarly, $-(\rho a l^4/g)\partial^2 u_o/\partial t^2$ is equivalent to a distributed force on the cantilever, which, though varying with time, is, at any given instant, the same at all points of the cantilever. $-(\rho a l^4/g)\partial^2 u_0/\partial t^2$ can accordingly be regarded as of the form

$$-(\rho a l^4/g)\frac{\partial^2 u_0}{\partial t^2}X(\xi)=-(\rho a l^4/g)F(t)X(\xi)$$

where $X(\xi)$ is, formally, regarded as a function of ξ which is constant (and equal to unity) over the range $0\leqslant\xi\leqslant 1$. It is then assumed that it is possible to express $X(\xi)$ in terms of the u_n in the form of the expansion

$$X(\xi)=\sum_{n=1} a_n u_n(\xi) \quad . \quad . \quad . \quad (31)$$

and substitution gives, after division by $\rho a l^4/g$,

$$\sum_{n=1}\left[\frac{d^2 T_n}{dt^2}+p_n^2 T_n+a_n F(t)\right]u_n(\xi)=0. \quad (32)$$

This latter equation will be satisfied if, for all n, the T_n will satisfy the equation.

$$\frac{d^2 T_n}{d\xi^2}+p_n^2 T_n+a_n F(t)=0 \quad . \quad . \quad (33)$$

whereupon (23) will constitute the required solution.

Supposing the cantilever to have been at rest until the motion was imposed on it, then, at time $t=0$.

$$y=\frac{\partial y}{\partial t}=0,$$

and it follows that, at time $t=0$,

$$T_n=\partial T_n/\partial t=o$$

The solution satisfying these initial conditions is

$$T_n=-\frac{a_n}{p_n}\int_o^t F(\eta)\sin p_n(t-\eta)d\eta \quad . \quad . \quad (34)$$

The foregoing procedure shows that the solution which has been evolved satisfies the terminal conditions imposed on y at $\xi=0$. It does not establish that the solution satisfies the terminal conditions imposed on y at $\xi=1$; but, formally this may be readily done by substituting the solution in the latter terminal conditions. To make the method satisfactory as regards mathematical rigour, it would be necessary to establish the convergence of the assumed series expansions and the legitimacy of the repeated term-by-term differentiations. This is not difficult for the present case, where $X(\xi)=1$, but it is a mere point of finesse which is not worth elaborating here.

In order actually to construct this solution, it is necessary to evaluate the a_n. For this purpose, use is made of two formulae due to Rayleigh, and a method given by Prescott. (*Applied Elasticity*, 1946, page 225) whereby finally

$$a_n=\frac{2K_n}{\lambda_n[1+\frac{1}{4}ku_n^2+\frac{3}{4}k_1(Du_n)^2]\xi=1} \quad . \quad . \quad . \quad . \quad (35)$$

Therefore, substituting in the expression for T_n

$$y=\sum_{n=1}^\infty u_n T_n$$

$$=-\sum_{n=1}^\infty\frac{2K_n u_n(\xi)}{p_n\lambda_n[1+\frac{1}{4}ku_n^2+\frac{3}{4}k_1(Du_n)^2]\xi=1}\times\int_o^t F(\eta)\sin p_n(t-\eta)d\eta \quad . \quad . \quad . \quad . \quad (36)$$

The deflection at the tip of the reed, where $\xi=1$ is thus given by

$$\delta=-2\sum_{n=1}^\infty\frac{G_n}{p_n}\int_o^t F(\eta)\sin p_n(t-\eta)d\eta \quad . \quad . \quad (37)$$

where

$$G_n=\left[\frac{K_n u_n}{\lambda_n\{1+\frac{1}{4}ku_n^2+\frac{3}{4}k_1(Du_n)^2\}}\right]\xi=1 \quad . \quad (38)$$

Technical Contributors Section (*Continued*)

If it is found that the effect of k_1 is negligible, then G_n is simplified, and is called B_n where

$$\left.\begin{aligned} B_n &= \frac{K_n u_n}{\lambda_n\{1+\frac{1}{4}ku_n^2\}}\,\xi=1 \\ \text{and} \\ K_n &= \frac{\cosh\lambda_n+\cos\lambda_n}{\sinh\lambda_n+\sin\lambda_n} \\ u_n &= \frac{2(\cosh\lambda_n\sin\lambda_n-\sinh\lambda_n\cos\lambda_n)}{\sinh\lambda_n+\sin\lambda_n} \end{aligned}\right\} \quad . \quad (39)$$

Application of Theory to an Impactometer

A typical impactometer is shown in Fig. 4 ;

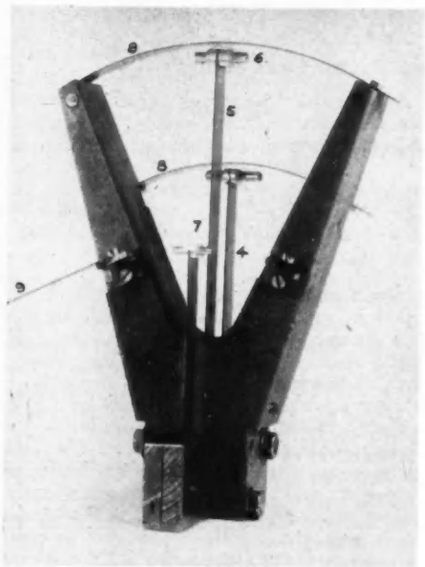


Fig. 4

and calculations are made for the deflections of reeds with their respective bob weights.

Table I

Reed	Reed length l, in	k	$K_n{}^2$ in^2	$\frac{k}{k_1}=\frac{l^2}{K_n{}^2}$	k_1
1 ...	3·248	0·22409	0·0360	293	$7·65\times10^{-4}$
2 ...	4·587	0·29472	0·0603	349	$8·45\times10^{-4}$
3 ...	6·792	0·250	0·0675	683	$3·658\times10^{-4}$

The values of λ_n, the characteristic numbers for three reeds, are given in Table II.

Table II

	Mode 1	Mode 2	Mode 3	Mode 4
Reed 1	1·59380	—	—	—
Reed 2	1·53867	4·14765	—	—
Reed 3	1·573145	4·20336	7·18055	10·0754

The shortest reed is No. 1 and the longest No. 3. The dimensions of the reeds and the values of k and k_1 are given in Table I.

Calculations of Periodicities

The periodicities of the reeds are calculated by means of Equation (26) where $g=32·2$ ft/sec^2, $\rho a=5·6777\times10^{-2}$ lb per foot. The values of E and I are difficult to determine directly when the reed is in the form of a flat strip nominally $\frac{1}{2}$in wide and $\frac{1}{32}$in thick. Static deflection tests were therefore carried out to determine the product EI. The values are given in the table below :

Reed	EI in lb ft^2
1	0·31901
2	0·34012
3	0·33843

From the above, the values of p_n, G_n and δ are given in Table III.

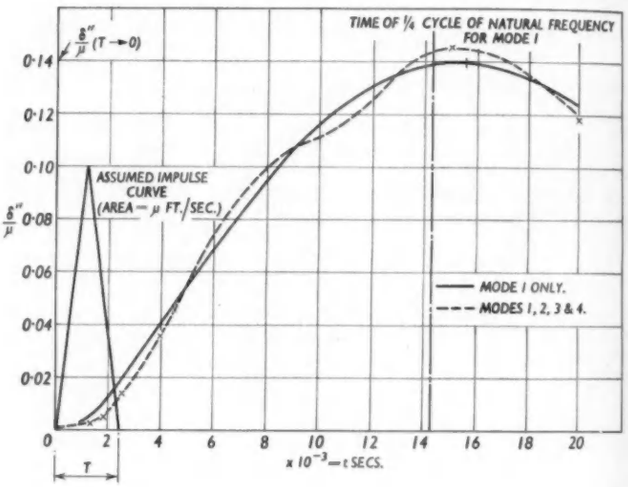


Fig. 5—Variation of δ''/μ with t (Reed 3)

Triangularly Shaped Shock Wave

The shock wave assumed is triangular in shape, the area of which is $\frac{1}{2}AT=\mu$ ft per second. For the first calculation T, the time it lasts, was taken to be $2·5\times10^{-3}$ seconds.

The application of Equation (37) to this form of shock wave consists, therefore, of three periods of time :

(1) $0\leqslant t\leqslant\frac{T}{2}$

$$\delta=-2\sum\frac{G_n}{p_n}\cdot\frac{2A}{T}\int_0^t\eta\sin p_n(t-\eta)d\eta$$

(2) $\frac{T}{2}\leqslant t\leqslant T$

$$\delta=-2\sum\frac{2AG_n}{p_nT}\left[\int_0^{T/2}\eta\sin p_n(t=\eta)\,d\eta+\int_{T/2}^{t}(T-\eta)\sin p_n(t-\eta)\,d\eta\right]$$

(3) $t>T$

$$\delta=-2\sum\frac{2AG_n}{p_nT}\left[\int_0^{T/2}\eta\sin p_n\,(t=\eta)\,d\eta+\int_{T/2}^{T}(T-\eta)\sin p_n(t-\eta)d\eta\right]$$

Evaluating the integrals, they become

(1) $0\leqslant t\leqslant\frac{T}{2}$

$$\delta=-8\sum\frac{\mu G_n}{T^2{p_n}^3}(p_nt-\sin p_nt) \quad . \quad . \quad (40)$$

(2) $\frac{T}{2}\leqslant t\leqslant T$

$$\delta=-8\sum\frac{u\,G_n}{T^2{p_n}^3}\left\{p_n(T-t)+2\sin p_n\left(t-\frac{T}{2}\right)-\sin p_nt\right\} \quad . \quad . \quad . \quad . \quad . \quad (41)$$

(3) $t>T$

$$\delta=-16\sum\frac{\mu\,Gn}{T^2{p_n}^3}\left(1-\cos\frac{p_nT}{2}\right)\sin p\left(t-\frac{T}{2}\right)=-32\sum\frac{\mu\,Gn}{T^2{p_n}^3}\sin^2\frac{p_nT}{4}\sin p_n\left(t-\frac{T}{2}\right) \quad . \quad . \quad . \quad . \quad . \quad (42)$$

δ is usually given in inches when the numerals -8 -8 and -32 become -96, -96 and -384 respectively.

It is now possible to plot the deflection at the bob weight for various times t ; and Fig. 5 shows this deflection for reed 3 in full line for the fundamental only and the dotted line with the inclusion of harmonics 2, 3 and 4. It will be noted that the time at which the maximum value occurs does not and

Table III.—*Maximum Deflection of Reed for an Impulse with a Triangular Wave Form for $T=2·5\times10^{-3}$ seconds*

Reed and Mode	(1) λ_n	(2) p_n	(3) G_n	(4) $\frac{24G_n}{p_n}$	(5) $\frac{384G_n}{T^2{p_n}^3}\sin^2\frac{p_nT}{4}$	(6) $\frac{384G_n}{T^2{p_n}^3}\sin^2\frac{p_nT}{4}\sin\frac{\pi p_n}{2p_1}$
Reed 1	1·59380	468·103	0·648266	0·033237	0·032298	—
Mode 1...						
Reed 2	1·53867	224·335	0·632115	0·067625	0·067183	—
Mode 1...						
Reed 2	4·14765	1630·09	–0·170964	–0·002517	–0·001758	0·001606
Mode 2...						
Reed 3	1·573145	109·8291	0·641597	0·140203	0·139983	0·139983
Mode 1...						
Reed 3	4·20336	784·103	–0·192295	–0·005886	–0·005429	0·004134
Mode 2...						
Reed 3	7·18055	2288·21	0·073079	0·000766	0·000367	0·000355
Mode 3...						
Reed 3	10·0754	4505·09	–0·029571	–0·000158	–0·000002	–0·000002
Mode 4...						
						Σ0·144470

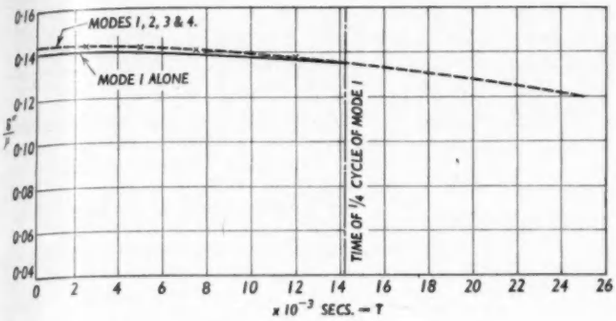


Fig. 6—Variation of δ''/μ with T (Reed 3)

should not agree with that of the reed vibrating freely.

When the duration of the shock is much less than the time of a quarter period of natural oscillation, the maximum deflection of the reed, due to the fundamental, takes place in period III, and it occurs (according to Equation (42)) when

$$p_1\left(t-\frac{T}{2}\right)=\frac{\pi}{2} \text{ or when } t=\frac{\pi}{2p_1}+\frac{T}{2}$$

at which time

$$\delta=32\frac{\mu G_1}{T^2p_1^3}\sin^2\frac{p_1T}{4} \quad \ldots\ldots (43)$$

Up to this point δ has been considered to be the deflection of the tip of the reed at any time t. After this, however, δ is to be taken to be the maximum deflection of the tip of the reed, i.e. when $\sin p_n(t-T/2)=1$.

At this point the other harmonics contribute to the maximum deflection according to the following relation :

$$\delta=-32\sum_{2}^{\infty}\frac{\mu G_n}{T^2p_n^3}\sin^2\frac{p_nT}{4}\sin\frac{\pi p_n}{2p_1}$$

and the values are given in Table III, columns 5 and 6.

The next question is how the maximum deflection varies with the total time of the shock wave.

Equation (42) has assumed for a maximum deflection the form of Equation (43) above, but when $T\to 0$ (μ still remaining constant), Equation (43) becomes

$$\delta(T\to 0)=-\frac{2\mu G_1}{p_1}=-\frac{24\mu G_1}{p_1}(\delta \text{ in inches}) \quad (44)$$

where only the fundamental is considered.

In Fig. 6 the value of δ''/μ is plotted for various values of T commencing at $T=0$ and for T of other values via Equation (43). This curve is relatively horizontal for values of T up to about one-half the time of one-quarter cycle of the fundamental, and therefore a good working formula by which an approximate maximum deflection can be calculated is given by Equation (44) where G and p refer to the fundamental only, and this applies so long as $pT\leqslant$ about 0·75. The values of $24G/p$ are given in Table III column 4, and in much of what follows, this equation is used exclusively, with the proviso mentioned above.

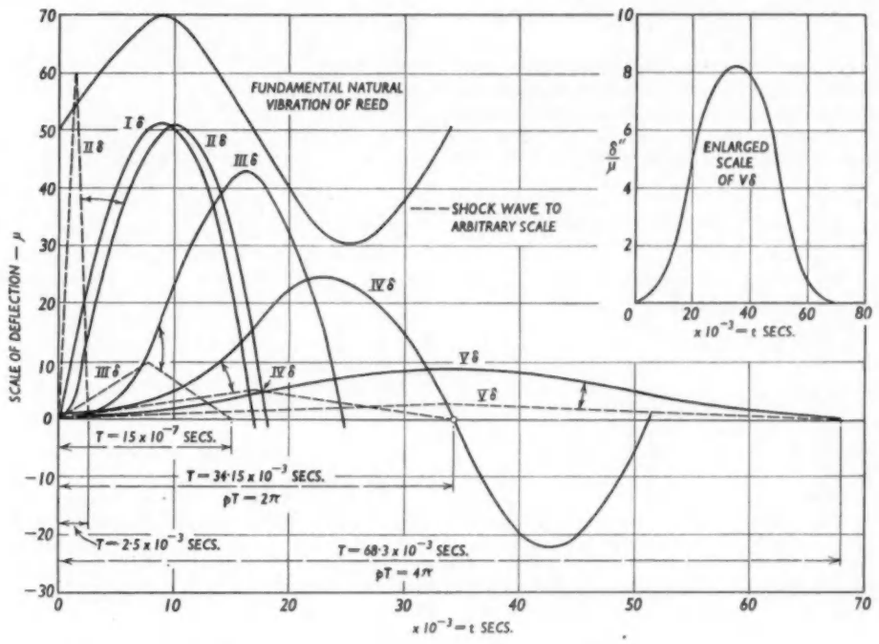
Effect of Time the Shock Lasts

The effect of a change in T is examined only for a triangular wave and for the fundamental mode. The three periods concerned are taken from Equations (40), (41) and 42.

In Fig. 7 the deflections of the reed for $T=0$, $2{\cdot}5\times10^{-3}$, 15×10^{-3}, $34{\cdot}15\times10^{-3}$ ($p_1T=2\pi$) and $68{\cdot}3\times10^{-3}$ ($p_1T=4\pi$) seconds are given ; and also the appropriate shock wave (shown dotted) which remains constant in area for each condition.

It will be seen from Equation (42) that the maximum amplitude obtained by putting $\sin p_1(t-T/2)=$ unity is determined by the ratio

$$\sin^2\frac{p_1T}{4}\Big/T^2$$



I δ	$\frac{\delta''}{\mu}$ FOR T = 0	
II δ	SHOCK	T = 2·5 x 10⁻³ SECS.
II δ	$\frac{\delta''}{\mu}$	
III δ	SHOCK	T = 15 x 10⁻³ SECS.
III δ	$\frac{\delta''}{\mu}$	

IV δ	SHOCK	T = 34·15 x 10⁻³ SECS. pT = 2π
IV δ	$\frac{\delta''}{\mu}$	
V δ	SHOCK	T = 68·3 x 10⁻³ SECS. pT = 4π
V δ	$\frac{\delta''}{\mu}$	

NOTE. THESE CURVES ARE DRAWN FOR VALUES OF $p_1=1{\cdot}8388\times10^2$ & $G_1=3{\cdot}9466\times10^{-1}$ AND NOT THOSE PREVIOUSLY GIVEN.

Fig. 7—Curves of δ''/μ showing how reed is deflected at different times t and for different values of T. μ = constant = $\frac{1}{2}AT$

and that this quantity is relatively constant so long as

$$p_1T\leqslant\frac{\pi}{4}$$

after which, as T increases, the ratio becomes rapidly smaller.

As T still further increases, there comes a time given by $pT=4\pi$ when the deflection occurs only in Periods 1 and 2, after which Period 3 affects the deflection to a very small extent. This is shown in Fig. 7, curve V.

Design of Impactometer

It is now possible to proceed to the design of an impactometer suitable for measuring impact, and such an instrument in shown in Fig. 4.

The fork of the instrument is made of bakelised fibre, and the three reeds are firmly clamped between two steel plates forming the base (1). Bolt holes can be seen in the figure for clamping the instrument where required. Too much emphasis cannot be placed on the necessity for clamping as rigidly as possible in all parts of the instrument, as any laxity in clamping will result in a large decrease in sensitivity and change in frequency. The sole reason for the bob weight (6) is to hold a spring steel wire stylus (7) which bears slightly on a steel strip (9) held in the form of a circular arc by brackets and screws.

As the reeds deflect, the stylus moves over the inner surface of the strip (9) which has previously been blackened by holding it in a sooty flame.

The instrument as designed cannot be expected to give correct indication of the shock without several correction factors. These are three in number :

(1) *Stylus Friction.*—As the stylus moves over the strip, it will be subject to friction effects ; and some little calculation shows that an approximate correction factor can be obtained if from the first two swings of the reed δ_1 and δ_1' (there and back) a corrected deflection $\delta_f=\frac{1}{2}(\delta_1+\delta_1')$ and this is made to the measured deflection.

(2) *Stylus Length.*—Since the deflection measured is of the tip of the stylus and not that of the reed a further correction must be made to δ_f whereby δ_f is reduced by a factor in the table to give δ_s.

Reed No.	Correction factor
1	1·09593
2	1·09868
3	1·04176

Technical Contributors Section (*Continued*)

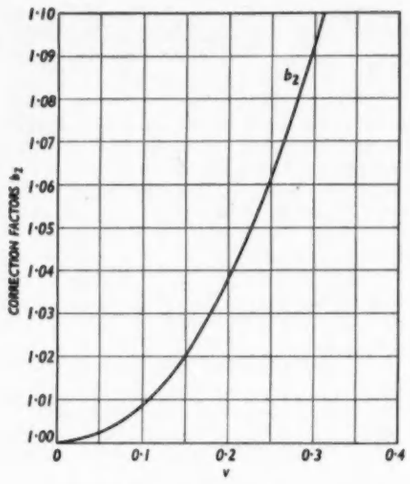


Fig. 8—Correction factor for large amplitude

(3) *Correction for Large Amplitude.*—Bernoulli-Euler theory of the flexural vibration of thin rods assumes that the displacement is small in comparison with the length of the rod. When the displacement is large the theory no longer holds ; and an assumption has to be made which is not strictly accurate. The calculated deflection is amended by multiplying it by a factor b_2 obtained from Fig. 8 where the abscissa v is obtained from $\delta = vl$.

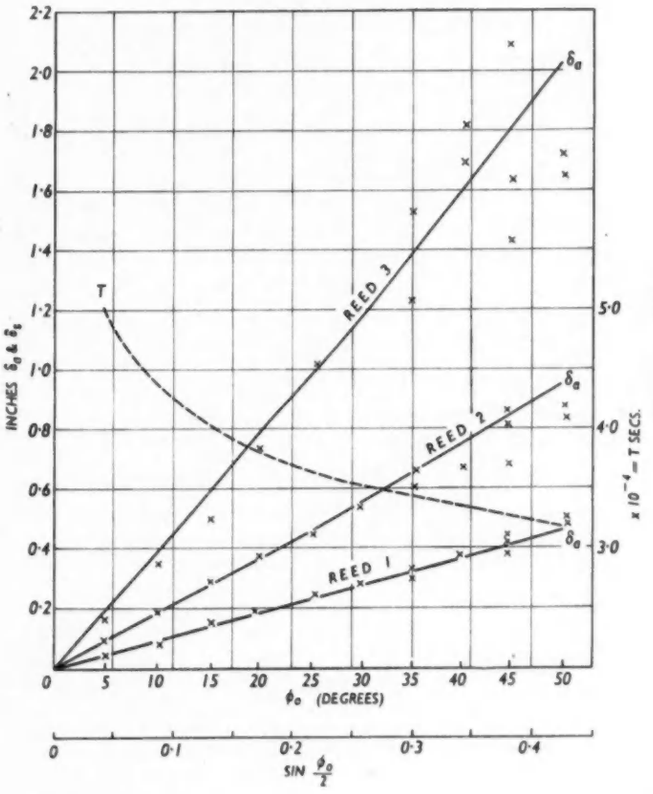
The final results are shown in Fig. 9 where the calculated and corrected deflections δ_a and the measured and corrected deflections δ_s are plotted against sin $\phi_0/2$ the sine of one-half the angle through which the sphere (or plate) is dropped"; also the total time the impact lasts T is shown dotted.

Discussion of Results

A careful scrutiny of Fig. 9 reveals some interesting features. The first is that in the case of reeds 1 and 2 up to $\phi = 30$ deg. the agreement between the calculated and measured deflections is surprisingly good considering the devious channels through which the calculations have been conducted. Secondly, the calculations of the behaviour of a reed when its root is subjected to shock ; and this has been the main concern of this analysis. Finally, the application of corrections to both the calculated and measured values as discussed above.

The only conclusion that can be drawn from these results (namely the agreement of reeds 1 and 2 for values of ϕ_0 up to 30 deg.) is that there is a reasonably good verification between theory and practice.

But there is a wide divergence at values of ϕ_0 greater than 30 deg., particularly on the longest reed No. 3. A tentative reason for these divergences is now given. In Fig. 4 the type of impactometer tested is shown, and it will be seen that the recording strips are held in position by square-headed screws ; and if these screws are thoroughly tightened, the strip should assume a circular form. But the path of the stylus cannot be circular, and only approximately so at very small amplitudes. The correction for friction assumes a constant frictional force, and it is doubtful whether this is attained in practice. In fact, if the screws holding the strips are not effectively tightened, the frictional resistance of the stylus may be quite erratic.



x Represents measured values corrected for friction and stylus length δ_s. The time of impact T is shown dotted.

Fig. 9—Continuous lines are calculated values corrected for large amplitudes δ_a.

The most disturbing departure from theory, however, is the lowness of the measured values compared with the calculated ones for reed 3 at values of ϕ_0 less than 25 deg. At the moment there is no explanation of this discrepancy.

In defence it must be stated that this impactometer was developed under war-time conditions, and it fulfilled its purpose as shocks of the order of only 10ft per second were involved.

After the war, the interest in it receded ; and it is only recently when certain aspects of shock have been revived that it was considered necessary to re-issue the early calculations.

When the difficulties have been resolved, it would appear that the vibrating reed impactometer may not need calibration, and that calculations only will give the required calibration curve.

The Reason for More Than One Reed

The impactometer illustrated has three reeds for which the various calculations have been made, but the reason for so many reeds is not immediately apparent.

In Fig. 9 for $\phi_0 = 30$ deg. the time of shock $T = 3{\cdot}5 \times 10^{-4}$ seconds, and the error due to this effect is seen to be negligible, and all three reeds should tell the same story as is the case in that figure. If the time of shock, however, had been 5×10^{-3} seconds, reed No. 1 would have given a result 11 per cent lower than reed 3, and reeds 2 and 3 would have given substantially the same result. Thus if the reeds suggest different impacts, the longest reed is likely to give the most accurate result, and if reeds 2 and 3 give the same result, this is likely to be the correct one. But, if all give different results, reed 3 is likely to be nearer the truth, although there is no knowledge how far away it is from the truth.

Acknowledgments

Thanks are due to the Research Laboratories of the General Electric Company for permission to publish this article ; to the Salford Electric Instrument Company for the construction of the Hertz calibrator and the impactometers ; and to A. F. Carnock for much help with the calculations.

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Centrifugal Stresses in a Single Wheel and Hub

By D. A. THURGOOD*

This article indicates how the normal method of stress analysis of a rotating disc may be modified slightly to cater for an abrupt sectional change, theoretical results being compared with recently published experimental data for a particular rotor.

THE designer is often presented with the problem of stress analysis within a single wheel and hub, where the axial length of the hub is considerably greater than that of the wheel. The normal treatment is to consider the wheel and hub as two separate annular rings and by equating radial loading and tangential strain at the common boundary, a two-dimensional stress system is obtained. This approach, by virtue of the assumptions made, gives rise

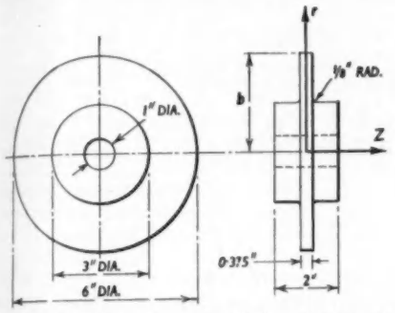

Fig. 1—Geometry of single wheel and hub with dimensions of photo-elastic model

to discontinuities in the radial and tangential stresses at the junction of the rings.

In the course of a photo-elastic survey of such a rotor, Guernsey[1] has shown that within the planes containing the thickness of the wheel no discontinuities exist and relatively steep stress gradients are present in the region of the wheel-to-hub junction. Further, he has shown that the bore tangential stress as obtained by the conventional analysis is some 10 per cent lower than that which exists in practice, as measured in the photo-elastic model. In this note a method of analysis is proposed which eliminates the discontinuities in the stress distributions and gives reasonably good correlation with the measured stresses from the photo-elastic model.

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Stress Distribution

Discs of varying thickness may be analysed by a " step-by-step " computation, as developed, for instance, by Manson[2], but these methods break down at an abrupt change of section, such as occurs at mid-radius in the rotor of Fig. 1. The transfer of loading from the wheel within the hub is a problem of load diffusion, the hub being fully effective in carrying its share of the wheel loading only at some distance away from the junction towards the bore. Some portion of the hub is therefore ineffective as load carrying material, and this effect must be included in the stress distribution calculation.

It is arbitrarily assumed that this ineffective material is outside a line drawn tangential to the fillet radius, and at 45 deg. to the plane of rotation, as shown in Fig. 4, with the ineffective material shaded. At radius r, the effective thickness is t, as indicated, and a " step-by-step " computation produces the stress distributions of Fig. 2 (radial stress) and Fig. 3 (tangential stress). These calculated stress distributions are compared with the measured values of reference 1, for the mid-plane section ($Z=0$) and at a section parallel to this at an axial distance of 0·137in ($Z-0·137$).

There is reasonably good correlation between the radial stresses calculated and measured at $Z=0·137$, particularly for the peak stress, there being only 3 per cent difference in magnitude and position between the two methods. Within the hub, however, i.e. $r/b<0·5$, the calculated stress is always lower than that measured. The tangential stress as calculated is considerably lower than that measured, the discrepancy being approximately 19 per cent at the bore, and 31 per cent at mid-radius.

In order to overcome these deficiencies, particularly in the calculated tangential stress at the bore, it is apparent that the ineffective hub material must be included in the analysis, for while it is not carrying load, it is producing load by virtue of rotation, and this has a significant effect on mid-plane

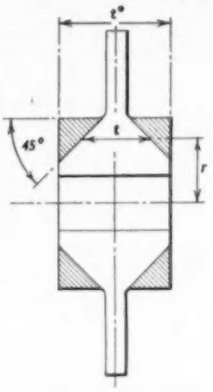

Fig. 4—Effective load carrying thickness t of model rotor

stresses within the hub. If the total thickness at radius r is denoted as t^* (Fig. 4), the normal equations used in the " step-by-step " method of :

$$\frac{\partial\sigma_r}{\partial r}=\frac{\sigma_\theta}{r}-\sigma_r\left(\frac{1}{r}+\frac{1}{t}\frac{\partial t}{\partial r}\right)-\frac{\rho w^2}{g}r$$

and

$$\frac{\partial\sigma_\theta}{\partial_r}=-\frac{\sigma_\theta}{r}+\sigma_r\left(\frac{1}{r}-\frac{\nu}{t}\frac{\partial t}{\partial r}\right)-\nu\frac{\rho w^2}{g}r$$

may be modified slightly to give :

$$\frac{\partial\sigma_r}{\partial r}=\frac{\sigma_\theta}{r}-\sigma_r\left(\frac{1}{r}+\frac{1}{t}\frac{\partial t}{\partial r}\right)-\frac{\rho w^2}{g}\frac{t^*}{t}r$$

and

$$\frac{\partial\sigma_\theta}{\partial r}=-\frac{\sigma_\theta}{r}+\sigma_r\left(\frac{1}{r}-\frac{\nu}{t}\frac{\partial t}{\partial r}\right)-\nu\frac{\rho w^2}{g}\frac{t^*}{t}r$$

Using these latter equations the calculated radial and tangential stresses are as shown in Figs. 5 and 6 respectively, again compared with the measured values of reference 1. Although the peak calculated radial stress is 6 per cent lower than that measured, the distribution generally compares very favourably with the measured values. The calculated bore tangential stress coincides with that measured, although elsewhere, except at the extreme radius, the calculated values are less than measured, to a maximum

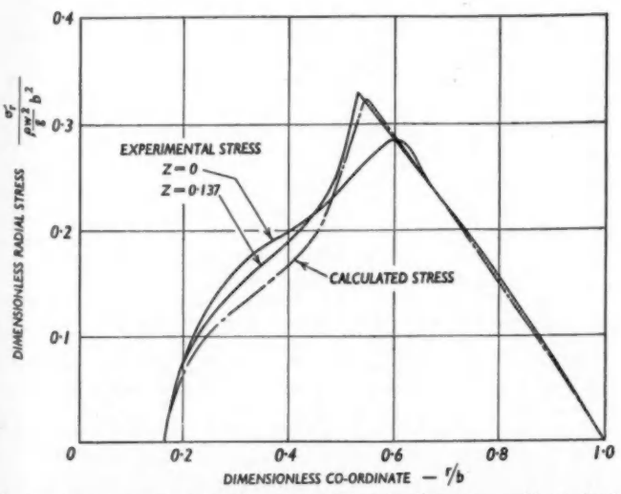

Fig. 2—Comparison of calculated and experimental radial stresses with non-load-carrying material ignored

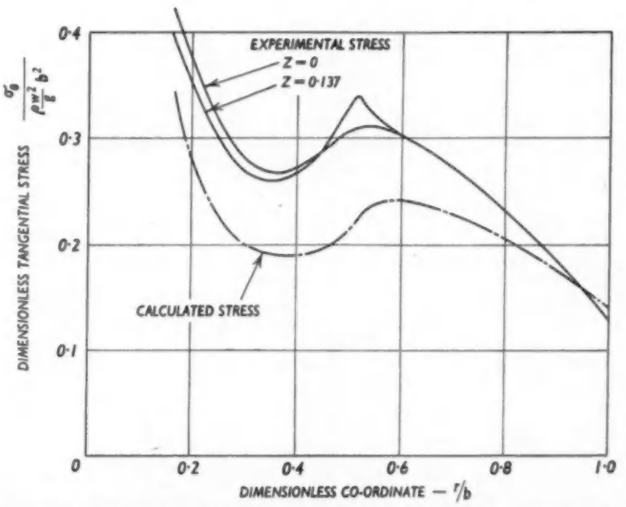

Fig. 3—Comparison of calculated and experimental tangential stresses with non-load-carrying material ignored

Technical Contributors Section (*Continued*)

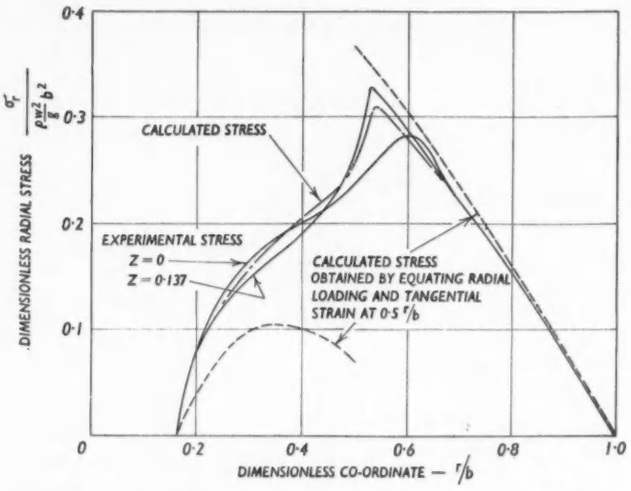

Fig. 5—Comparison of calculated and measured radial stresses with non-load carrying material included

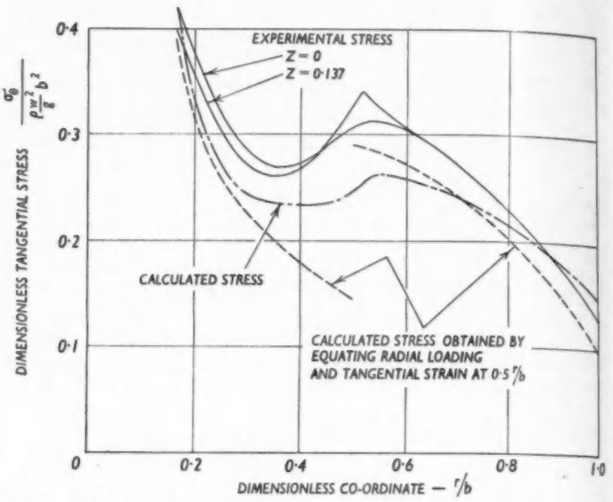

Fig. 6—Comparison of calculated and measured tangential stresses with non-load carrying material included

discrepancy of 21 per cent. For comparison, in Figs. 5 and 6 the calculated stresses are shown as obtained by the normal method of equating radial loading and tangential strain at the wheel to hub junction, exhibiting the discontinuities unavoidably associated with the assumption that at $r/b=0.5$

$$\sigma_{rHUB}=\frac{t_{WHEEL}}{t_{HUB}}\sigma_{rWHEEL}$$

Conclusions

Based on the evidence of a photo-elastic analysis of a particular geometry, it may be stated that a rotor in which there is an abrupt change of thickness may be analysed by a " step-by-step " method by assuming that all the material is fully effective in producing load, but some portion is in effective in carrying load. With an arbitrary choice of a straight line " diffusion profile " and 45 deg. " diffusion angle," reasonably good correlation has been obtained between calculated and measured radial stress distribution and bore tangential stress. It is possible that an investigation of different " diffusion profiles " would have resulted in better agreement between calculated and measured tangential stresses. This, if successful, would have resulted in a " profile " for one particular rotor geometry only, and it is suggested, in the absence of other evidence, that the straight line " profile " at 45 deg. may be applied to all abrupt changes of thickness to give reasonably reliable stress distributions, irrespective of overall rotor geometry.

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[1] Guernsey, R., Jr., " Photoelastic study of Centrifugal Stresses in a Single Wheel and Hub," *Experimental Mechanics*, Vol. 1, No. 1 (1961).

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Research of the Gas Industry

A number of interesting papers were presented in the course of the autumn research meetings of the Institution of Gas Engineers which have been in progress during the past week. In one of these papers Sir Charles Ellis, the scientific adviser to the Gas Council, described the pattern of current research in the gas industry. This paper provided a clear, concise review of current research and we reproduce some abstracts from it below.

THE Gas Council has decided that its major effort in research shall be directed at total gasification to produce a gas of the highest purity and lowest cost. This may seem such an obvious statement as to be of little value, but, on more detailed examination, it will be found fully sufficient to provide the kind of guide required. One immediate consequence of this emphasis on total gasification is that research on the classical carbonisation process will not figure largely in the Council's plans. This does not, of course, mean any reduction in the major role of carbonisation in the production of gas, indeed it will continue to provide the greater part of the industry's gas for many years to come, but that the technical knowledge from the comprehensive researches already carried out by the industry should be able to deal with any future problems that might arise, and that the creation of new technical knowledge in this field is not considered so vital as in the field of total gasification.

The question of cost should, according to current thought, be considered in relation to the following requirements :

(1) The ability to use any available solid, liquid, or gaseous fuel as the raw material for gas manufacture so as to take advantage of the market conditions ruling at the time.

(2) The ability to effect the conversion of such raw material to finished town gas at an overall cost not greater than 2·5 times the cost per therm of the raw material.

(3) To effect the conversion in plant whose capital cost is sufficiently low for it to be operated at the low load factor associated with domestic space heating.

Cost is coupled with purity in the directive, and these two points are fundamental to the policy of the Council's research on utilisation. While the phrase " cost to the consumer " is usually taken to mean delivered cost, that is, the cost of production and transmission, in the wider sense it also involves what the consumer must expend on appliances and what efficiency of utilisation he obtains for this expenditure. Both of these are closely dependent on the purity of the gas. Reduction in the organic sulphur compounds remaining after normal purification could with advantage be taken to a figure as low as about 2 gr per 100 cubic feet, when appliances could be designed for use at higher efficiencies, and troubles due to corrosion would virtually not occur.

Reduction of carbon monoxide is also classified under purification, and the Council has recommended to the Area Gas Boards that new plant should provide gas with a carbon monoxide content below 5 per cent.

Both of these improvements in the quality of the gas would be welcomed by the consumer, but, although it is hoped they would lead to a greater popularity for gas, their cost could scarcely be met by increasing the price. The quite considerable cost of installing and running plant to give these improvements on existing streams from conventional gas-making systems might add about 1d. per therm to the running costs of the complete process. If, however, the purification processes were " built-in " to the new gas-making process, it might well be possible to achieve improved purity without additional overall cost : for example, the cost of carbon monoxide conversion could be more than counterbalanced by the fact that the conversion would allow the introduction of a ballast gas and the use of more enrichers. Detailed technical considerations of this nature must not, however, obscure the point that an important reason for introducing these improvements would be to increase the industry's ability to maintain or to increase sales in the face of competition.

It is impossible, within the limits of this paper, to survey completely all of the Council's researches, and I trust I may be allowed to select for rather more detailed discussion just a few items which illustrate the general approach and indicate the scope of the attack on the problem.

Purification

" Purification," in the context of this paper, refers to the treatment of gases prepared by some process of total gasification of coal or oil, but I shall refer only to those researches designed specifically to deal with the gases likely to be produced by the industry's own pressure processes.

The only method of reducing the carbon monoxide content of gas which is worth consideration on grounds of cost is the water gas shift reaction in which the carbon monoxide reacts with steam over a catalyst to give hydrogen and carbon dioxide. Subsequently, part of the carbon dioxide is removed by absorption using one of a number of methods. The simplest case is the shifting of lean gas, using iron-oxide-chromia catalysts. This process would be applicable not only to the new types of gas, but also to existing gases, such as, for example, carburetted water gas. With clean gases, the catalysts age slowly and the only side reaction, that of methane synthesis, can be prevented by a small excess of steam. A practical problem that serves to illustrate and define the field of research is that of gas at about 20 atmospheres from the Lurgi process. The Steinkohlengas Company of Dorsten has recently been experimenting on the pilot-scale by reacting the crude gas from the gasifier over a molybdenum sulphide catalyst before the removal of water vapour, light oils and hydrogen sulphide. It is claimed that it is possible with one single catalyst to effect the water gas shift reaction, hydrogenation of sulphur compounds and the hydrocracking of hydrocarbons. Several advantages appear to attach to this process : it economises in steam and heat exchangers, improves the quality of the light oil by desulphurising it and reducing the unsaturated hydrocarbon content, increases the production of benzole at the expense of tar, and reduces the volume of effluent liquor and the proportion of polyhydric phenols in it, but, so far, all knowledge is of an empirical nature. The Gas Council has, therefore, decided to arrange for a careful study of the chemical reactions involved, the investigation of a number of different catalysts and the effects of adding to carbon monoxide, hydrogen and steam, a proportion of contaminant such as hydrogen sulphide, benzene, thiophen or *n*-heptane. This work is being undertaken by Mr. G. U. Hopton at the London Research station and is estimated to take about three years to complete at a cost of £40,000.

Reducing the carbon monoxide to about 5 per cent results in a carbon dioxide content of 30 to 40 per cent, and this has to be reduced to ensure satisfactory combustion characteristics. Precisely how much can be left in depends on each individual production unit, and it can well be advantageous to remove more carbon dioxide than theoretically necessary for obtaining correct combustion characteristics and replace it by nitrogen as a ballast gas, since this permits the addition of more of the cheap enriching therm, which might well result in counterbalancing the extra cost of this part of the process. There are many commercial processes available, but there are still several important points on which the lack of fundamental information makes it difficult to ensure the best design for each particular case. The absorption of carbon dioxide is controlled by a slow chemical reaction, so slow that there is scope for evolving cheaper methods, which might be variants of existing methods. Mr. Hopton proposes a comparative study of various contacting devices, measurements of the chemical rate processes under conditions where physical effects on absorption rate are slight and well defined, and comparisons between the various methods of improving the rate of chemical reaction in aqueous potash wash liquors by increasing the temperature of washing or by means of additives. Attention will also be given to new solvents for the physical absorption of carbon dioxide from gases at pressure. This work has now been started at the London Research Station and is expected to take about four years and cost a little under £140,000.

A more ambitious project, involving much more exploratory research, is to find one single process for removing hydrogen sulphide from gases at 20 atmospheres in the presence of considerable quantities of carbon dioxide. The traditional iron oxide method is not suitable for the main absorption, since the pressure prevents the evaporation of water formed in the reaction, while liquid processes currently used involve a multiplicity of steps. It appears that, both at Westfield and at Coleshill, removal of the greater part of the hydrogen sulphide by reversible absorption in an aqueous wash liquor must be followed by secondary purification using iron oxide in pressure tower purifiers, and there still remains the problem of converting the hydrogen sulphide from the primary purification systems, much diluted with carbon dioxide, to sulphur or sulphuric acid. It is obviously an important objective to search for a single process that will remove all the hydrogen sulphide with the production of sulphur sufficiently pure to be saleable. Mr. Hopton proposes to undertake a thorough study of possible oxidation-reduction systems working at pressure. The work will take at least four years and, including pilot plant, the cost may well approach £150,000. The difficulty of the research is fully recognised, and it will be necessary to employ the most modern advanced methods of studying fast reactions in order to have a reasonable chance of disentangling the complicated reactions. There

is here a field for some longer-term basic laboratory research to explore possible reaction systems from a very general point of view.

One example of such a system, the Stretford Process, using anthraquinone disulponate, has been developed for removal of hydrogen sulphide at ordinary pressures, and Mr. J. E. Davis, O.B.E., is carrying out a pilot-scale study of this process applied to gas at high pressure in a plant at the South Eastern Gas Board's Sydenham Works. The study will provide practical operating experience, and will, where necessary, be supplemented by laboratory investigations.

It will have been noticed that these three chemical engineering studies are all planned to achieve their objectives within three to four years and are designed to treat product gas from total gasification at about 25 atmospheres. By that time, considerable full-scale experience will also have been obtained from the commercial operation processes ancillary to the Shell gasification plant at Grain and the Lurgi plants in the Scottish and West Midlands Gas Boards, and the sum total of knowledge should be sufficient to deal with the problems that will be raised by any new plant that might then be under construction.

Total Gasification at Pressure

The successful commissioning at Westfield of a Lurgi plant demonstrates the technical feasibility of using this generator on British coals, and constitutes a major advance. It has even been said that the total gasification of coal has been mastered, that all that is now required is to put up Westfield-type plants as fast as possible. This is an important point which cannot be dismissed lightly and to which much serious thought has been given, but, however striking may be the achievement of getting a Lurgi to work on British coals, it can only be considered as a first step. At the present cost of coal, it cannot compete with some oil-based processes, and the very heavy capital requirements are unattractive in view of a possible trend to lower load factors. The Gas Council feels, therefore, that research on total-gasification processes using a variety of feedstocks must be pushed in order to broaden its knowledge of future possibilities.

Over a number of years Dr. F. J. Dent, O.B.E., has been investigating many aspects of high-pressure gasification of coal, and most of his researches have been reported to this Institution. At the Twenty-fourth Autumn Research Meeting, Dr. D. Hebden and Mr. R. F. Edge described the work they had carried out under Dr. Dent, at the Midlands Research Station on operating an experimental fixed-bed gasifier under slagging conditions. The early experiments were undertaken with coke and at only 4 atmospheres, but these were capable of showing the improvement resulting from working at a higher bed temperature. The authors were able to estimate the comparative performances for a typical high-volatile, weakly caking coal under both slagging and dry ash-removal conditions, and the following table from their paper gives some of their figures.

While these are only estimates, they suffice to bring out the differences between the dry ash- and slagging-type generator. First of all, there is much less steam used, and this, combined with the higher reaction temperature, results in a smaller production of liquor. This will cheapen considerably the recovery of both ammonia and phenol, and simplify the ultimate disposal of the effluent. On the other hand, more oxygen is used. In the crude gas from the dry-bed gasifier, there is 28 per cent of carbon dioxide, but only about 6 per cent in the slagging type. This will facilitate the removal of sulphur compounds at an early stage of gas treatment, and hence, also, the removal of the carbon dioxide produced subsequently during carbon monoxide conversion. When it is remembered that well over 2d. per therm can be involved in reducing carbon monoxide and removing carbon dioxide and sulphur compounds, it is obvious how important are any factors that affect these operations. The Committee on Coal Derivatives considered that it might prove to be somewhat more expensive to transform raw gas from a slagging gasifier into town gas than to do so for raw gas produced by a conventional Lurgi gasifier, but, weighing up all the factors of effluent disposal, greater specific throughput and ability to use a greater variety of coals, it recommended that this development should be pursued.

Estimated Performance for a Typical High-volatile Weakly Caking Coal in a Slagging Gasifier Compared with that Obtained in a Gasifier with Dry Ash Removal

	Slagging	Dry Ash
Process steam (lb per therm)	3·8 to 3·0	17·9
Oxygen (cubic feet per therm)	54 to 64	48
Final reaction temperature (deg. Cent.)	1,250	750
Gas yields (therms per ton dry coal) ..	262 to 257	267
Calorific value (B.Th.U. per cubic feet)	375 to 360	400
Liquor (lb per therm)	0·9 to 2·1	12·0
Thermal efficiency (per cent) including oxygen production and carbon monoxide conversion...	72·4 to 68·9	67·8

The latest state of the work is that an ingenious type of slag tap has been worked out in which a jet of burning gas both keeps slag molten in an exit pipe and, by its impact, supports the pressure from the inside of the gasifier. Modifications in design are now being made and new pilot-scale experiments due to start in mid-1962 should provide enough information to estimate the performance of a full-scale plant.

The experiments at the Midlands Research Station on the slagging gasifier have now reached the stage where the gas output will be about 5,000,000 cubic feet per day, and corresponding supplies of fuel, steam, oxygen, &c., will be needed. The result is that it has been found necessary to move the whole plant out into the open, and all this takes time. It is scarcely possible to expect definite results based on extended runs until early in 1964, although it might be justifiable to take preliminary planning decisions about a prototype towards the end of next year.

To complete this account of experiments on the total gasification of coal, a brief reference must be made to the investigations of Mr. Hopton, at the London Research Station, of the Otto-Rummel Double Shaft slag bath. This operates at ordinary pressures and is being erected as a pilot plant, of 2,000,000 cubic feet per day, by Simon-Carves, which holds the licence from the German firm of Otto. The size of a production plant could be quite small and suitable for using a moderate supply of local cheap coal. This system is therefore complementary to Lurgi which must be served by an economically large size of oxygen plant and must be sited near a very large supply of cheap coal.

With the dry-bed Lurgi already working on a commercial scale and with a high probability that the slagging fixed-bed gasifier will be technically successful, and also with a fluidised gasifier a good—if longer-term—possibility, it is reasonable to consider the total gasification of coal as one of the future major generating processes. Any decision on this point, however, will be primarily economic, not scientific. Such gas would require enrichment. Fortunately, at the moment the petroleum gases constitute a cheap therm and are in adequate supply from the various refineries. There are good reasons to expect this situation to continue, and a growth of methane imports would provide a valuable insurance. All the same, it is an obviously important line of research to endeavour to broaden the sources of the enrichment gas, and Dr. Dent has devoted much attention to this point and has gone a long way to produce practical methods of making rich gas from crude and heavy oil. It will, of course, also be appreciated that these are complete-gasification methods in their own right, and can be arranged to make town gas uniquely from oil.

Starting from crude or heavy oil as a feedstock, Dr. Dent uses his well-known hydrogenation reaction. The oil already contains a fair quantity of hydrogen combined with carbon, and the object is to add more so that in principal methane results. This reaction is exothermic and its practical realisation poses acute chemical engineering problems. Dr. Dent has worked out an extremely ingenious way of controlling the reaction by using the oil and hydrogenation gas to fluidise a column of coke which is continuously circulating by return through a non-fluidised downcomer. The fluidised coke bed ensures a controllable, even distribution of the exothermic heat besides giving a large surface for reaction. A pilot plant operating at 1,000,000 cubic feet per day has been built. After extensive experiments on light oils, it was run early this year on Iranian crude oil making gas of 800 B.Th.U. per cubic foot. It is interesting to note the distribution among the products of the carbon supplied as oil.

Hydrogenation at Pressure of Iranian Crude Oil : Percentage Distribution Among the Products of the Total Carbon Supplied

Gas	69
Benzine	10·6
Toluene and other monocyclics	2·8
Naphthalene	2·6
Higher polycyclic aromatics...	11·7
Carbon deposited	3·3

On a full-scale plant, it is possible that the higher aromatics would be returned for further hydrogenation to gas, benzene and naphthalene. This experiment, while showing the need for some further modifications in design, gives great promise of success. A run aimed at increasing the calorific value continued for four days during which a calorific value of 900 B.Th.U per cubic foot was achieved. The next stage in this work will be to use heavy oil.

When this process is to be used to enrich shifted gas from a coal-gasification plant, it will be necessary only to send part of the hydrogen-rich gas stream through the hydrogenator. It would appear that approximately 1 ton of oil is required to enrich the gas produced from 5 to 6 tons of coal.

In view of this good progress, the enrichment of the gas obtained from the total gasification of coal seems to be reasonably safeguarded, either by the purchase of refinery gases, by imported methane, or by the manufacture of rich gas by hydrogenation of light distillate, or crude oil, but yet The Gas Council considers it should also fully explore the possibilities of obtaining a source of enrichment based on coal. The possibility of this rests on Dr. Dent's investigations into the hydrogenation of coal, the latest account of which will be found in the Ninth Coal Science Lecture which he gave to the British Coal Utilisation Research Association in the autumn of 1960.

To complete this picture of the pattern of research in the gas production field, mention

must be made of a process for the production of town gas by the catalytic interaction at high pressure of light distillate and steam. The process consists, broadly, in reacting steam with light distillate at relatively low temperatures over a catalyst to produce a methane-rich gas which is then reformed to town gas at a higher temperature generated autothermically by the addition of air. A preliminary stage is also included for the removal of sulphur compounds from the light distillate. The process can also be operated using methanol as the feedstock, in which case the desulphurisation stage is not necessary.

The process was initially designed to minimise capital charges for peak loads, but it is now attracting attention for use on base load. Operation is at the high thermal efficiency of 85 per cent and plant units can be of very high output: for example, 50,000,000 cubic feet per day can be made in reaction vessels 10ft in diameter. At the same time, the process can also be operated economically in small units, and this, combined with its simplicity and the automatic nature of its operation, make the process especially suitable for peak-load purposes. It has now reached the stage where full-scale plants could be designed.

Conclusion

The dominant development in the industry to-day is total gasification, and the pattern of the Council's research effort is one of focusing more and more of its efforts towards this aim. One possible solution that has emerged is along the broad lines of making a hydrogen-rich gas by reaction of coal with steam and oxygen, and enriching this with refinery gas or a rich gas made by hydrogenation of crude or heavy oil. The immediate question is whether the coal gasification is going to take place in a conventional dry-bed Lurgi or in a slagging fixed-bed generator with introduction of the reacting gases through tuyeres. It seems unlikely that this can be answered before the middle of 1963, and it will be still later before the further possibility of treating coal in a fluidised bed will be worked out. It is time-scales of this nature that may have prompted the suggestion that the industry should spend more on research. This kind of remark often arises, not so much from a technical misunderstanding of the subject from a feeling of wanting improvements at once, and using the word "research" as a kind of magic that can be bought by money. Sir Henry Jones, Chairman of the Gas Council, has dealt shortly with this attitude by remarking that you do not do research by signing a cheque, but even if this type of recommendation represents only general uneasiness, we should all the same examine whether there is substance behind it. Ought the industry to have doubled the scale of research? It might be that it should, but, even if hindsight is allowed, it is difficult to say this with conviction, and it is more difficult still to say what the results of a higher rate of expenditure would have been.

On the whole, I think the Council's researches have prospered, and it has made progress that compares well with similar development projects in America and Germany. What is certainly true is that nothing can now be done which will drastically accelerate the conclusion of the experiments on the slagging fixed-bed gasifiers, since these will have produced a result, one way or the other, before any new experiment could contribute anything.

It is only fair to recall that the research data on the hydrogenation of crude and heavy oil are adequate to justify a full-scale experimental plant, but this would be expensive and could scarcely be undertaken without the reasonable certainty that a successful outcome would be held to justify the wider use of such feedstocks. The catalytic gasification of light distillate is also ready for full-scale experiments.

All of the researches that I have used to illustrate the pattern of the Council's work, and the majority of the other researches that I have not been able to refer to, are to-day in, or very close to, the application stage, that is to say, it is hoped that their results are soon going to be put to work, and this prompts the query as to what will be the basis of the Council's application research in, say, ten years' time. Where are we going to get the new ideas, where are we going to do the laboratory work from which will emerge those new methods of making, or of purifying, or of utilising gas which we hope to be developing in ten years' time. The answer is that we must do the laboratory work ourselves, and this is precisely what the Gas Council has in mind in starting a new group on basic research.

Some basic research is being done at each of the Council's three establishments, and figures largely in the work at the University of Leeds under the Livesey Professor, Dr. A. L. Roberts. However, the Gas Council considers that this basic research work must be increased and in a way which, while keeping it in close contact with the industry, will yet protect it from disturbance by the intrusion of immediate development problems. It is too early to speak about the programme of the Group, since a scientist has only just been appointed as head. His first task will be to think widely about the future of gas and to try to identify a few lines of research that have a reasonable chance of breaking new ground. I am confident this can be done, and indeed, now that the Council has taken this decision, I am less worried about 1974 than 1964.

I hope that the Council's researches appear as a balanced programme, but ours is a complex industry extending from large-scale manufacturing processes right into the details of domestic use, and it would be expecting too much to hope that the emphasis of the Council's research is correct at all points. All I would claim is that its research has a pattern, and one that is sufficiently simple to be easily grasped, and therefore, I hope, constructively criticised.

Non-Destructive Testing in Electrical Engineering

No. II—(*Concluded from page 815, November 17, 1961*)

A conference on non-destructive testing in electrical engineering was organised by the Institution of Electrical Engineers and held in London from November 8 to 10. Many of the papers dealt with specialised aspects of the subject but some, which may be of general interest to other branches of engineering, are summarised below.

Detection of Concealed Internal Faults

A session on concealed internal phenomena included two papers on the detection of leaks. In the first of these P. F. Berry and J. K. Cameron discussed the use of a radioactive gas (^{85}Kr) for leak detection in sealed electrical components. Two methods were described.

The first method, which is suitable for use in testing large numbers of small components, involves measurement of the rate at which the gas leaks into components under a pressure differential. The components are placed in a pressure vessel which is then filled with ^{85}Kr at a pressure of about 50 lb per square inch (gauge). After a predetermined immersion period the gas is returned to a storage vessel, the components are removed and the amount of ^{85}Kr gas in each is measured with a scintillation counter. Leaks as small as 10^{-11} standard-ml/s can be detected and measured (in a typical test) on 500 components in an hour. In this way the leak rate of several thousand encapsulated transistors has been measured (at one of the establishments of the United Kingdom Atomic Energy Authority) and the results have been correlated with electrical failure under humidity cycling.

In the second method (suitable for small numbers of larger components) the items to be tested are filled with a few microcuries of ^{85}Kr before the final sealing. Then each component is put, separately, in an evacuated enclosure and the gas that leaks into the enclosure from the component is collected and pumped into a scintillation counter.

Leak testing during the manufacture of sealed-off vacuum devices was the subject of a paper by R. O. Jenkins, who described and discussed the various methods available. For smaller leaks the magnetic type of helium mass spectrometer is the most generally suitable test equipment but its use is limited by the fact that it is unsuitable for large leaks and that its ultimate sensitivity is two or three orders smaller than would be desirable. However, the author concluded that this disability may have been overcome by a modified form of spectrometer described by J. L. Peters in the *Review of Scientific Instruments* 1959, vol. 30, page 1093. The main limitation of the conventional helium mass spectrometer results from the background current caused by ions of the wrong mass, scattered by collision with gas molecules, reaching the collector. In the new instrument there is a second magnetic analysing system, to prevent these scattered ions from reaching the collector. Thus the background current is considerably reduced. A more sensitive ion-current measuring system can then be usefully employed and a secondary-emission electron-multiplier is included in the spectrometer head. It is claimed that this system will detect leaks down to 10^{-13} l-torrs/s, which is what is really required. It may not always be economically practicable to use this sensitivity in routine testing because of the time taken for helium to percolate through such very small leaks, but this new equipment may well prove to be a considerable advance on the present ones.

The applications of xeroradiography to

the inspection of electrical equipment were described and illustrated in a paper by A. Nemat, A. W. Balls and W. F. Cox.

Xeroradiography is a radiographic inspection technique in which the film is replaced by an electrically-charged selenium layer which is exposed in the conventional way and developed by spraying the plate with a fine powder. By electrostatic attraction this will form an image which can be inspected about a minute after exposure and is recorded photographically by a miniature or Polaroid camera. The powder image is brushed off and the plate is used again.

The main characteristic of this image, compared with a conventional radiograph, is that it shows enhanced contrast for flaws and section changes of the object; the sharper the thickness change, the higher is the contrast. Gradual changes of thickness, however, are shown with very low contrast. Two consequences are of interest. First, the xeroradiograph shows up some cracks and other inhomogeneities more readily than the normal radiograph; secondly, it covers a much wider thickness range without loss of contrast. A disadvantage of the contrast enhancement is that it may obscure features near the thin side of section changes. On the other hand prints can be reproduced at very low cost, without loss of contrast, and they can be inspected in daylight.

The use of filters at the X-ray tube and plate, specimen masking and elimination of back-scatter were examined by the authors. It was found that heavy filtration, compatible with reasonable exposure time, usually led to improved contrast, and masking was necessary on objects in excess of ½in of brass or steel.

Applications in the electrical industry cover a wide range. The method is mainly used as an aid to design departments: the quick development of the radiographs and the fact that a number of radiographical prints are available are found useful both in the drawing office and in design conferences. In the inspection of graphite components used in the construction of nuclear power generators, xeroradiographs yield pictures in which cavities and cracks are easily seen. In communications and electronics, many subjects are found which call for radiography, particularly in the development stage, where it may be desirable to confirm correct assembly before proving tests are carried out. Electronic tubes are very suitable subjects for xeroradiography since their component electrodes are better demonstrated with enhanced boundary contrast. Thickness contrast in these subjects is relatively unimportant or may even be undesirable. Resin-encapsulated assemblies of components allow a quick check of correct positioning. They are thus a suitable subject for this method. Similarly the internal conductors of concentric cables and connectors can be examined for centrality.

A stroboscopic X-ray system, described in a paper by L. W. D. Pittendrigh, offers a useful means of observing the behaviour of electrical and mechanical devices during vibration when the parts are hidden by protective enclosures. The method is specially applicable to components and mechanisms, such as relays, encapsulated in epoxy resins for service in aircraft or guided missiles. Briefly, the system described by the author consists of a pulsed X-ray beam, producing an image on a fluorescent screen. The limitations of the fluorescent screen—including the low level of illumination and the poor definition compared with a radiograph—are overcome by the use of an image intensifier which gives a brightness gain of about 1000 over a simple screen and allows a small focal spot to be used.

Of the many methods of modulating the X-ray beam the one chosen for development in this instance was the one using contra-rotating shutters. Each of the two rotating discs or shutters contains four equally-spaced slots which coincide, to transmit the beam, 150 times per second, at a shaft speed of 2250 r.p.m. The main requirement of the drive was that it should allow adequate rate of change of speed control at all values up to 150 c/s without overspeed or hunting. A d.c. motor with a split field system was found to give this control to ±1 per cent.

To reduce the loss of detail resulting from scattering of X-rays in the test component, adjustable, rectangular, horizontal and vertical shutters are placed in the beam path near the contra-rotating shutters. These rectangular shutters, operated by Bowden cables, enable the area of the beam to be restricted to a particular part of the test object. The whole equipment is enclosed in a cabinet with a lead lining 5mm thick to protect the operator by reducing the radiation level to less than 1 millirad per hour. This apparatus has given good results in the examination of electrical components and sub-assemblies subjected to vibration, as shown by films that accompanied the author's paper.

Contacts and Joints

A session devoted to contacts and joints included a paper by A. C. Delamere and R. T. Weeks, on the testing of solderless wrapped connections. These connections are formed by wrapping a conductor wire directly round a terminal with controlled tension. The wrapping is done with the aid of a simple tool, either hand-operated or power-operated.

In a series of tests (described by the authors) including heat ageing, freezing and temperature cycling, extending over a period of about eleven months, wrapped and bound joints proved to be extremely reliable, but the results emphasised the need for careful handling of joints. The results also indicated that there is a general tendency for the resistance of all solderless wrapped connections, both wrapped and bound, to increase slightly with time, the rate of increase being greatest on the wrapped joints. Immediately before failure, the change in resistance of 200 bound joints in series totalled less than 20mΩ. For 200 wrapped joints in series, the increase was approximately 50mΩ. Individual measurement of each connection showed that the increase was uniformly distributed. After the initial relaxation, by heat ageing, the change in resistance with time was uniform.

During limited investigations to study the effects of vibration on bound joints, it was noted that the performance curve for a tinned-copper/tinned-copper/tinned-brass combination was very similar to that for non-vibrated specimens. However, on bound joints having beryllium-copper wrapping wire, the d.c. resistance was found to have decreased after the initial conditioning at 175 deg. Cent. After this initial drop the d.c. resistance/time curve ran almost parallel to that for the unaged specimen.

It has been suggested that, although the hoop stress in the wrapping wire decreases with time, the efficiency of the joint improves owing to a diffusion process. Attempts were, therefore, made to determine whether in fact diffusion did take place.

Initially, specimen joints were produced and a microscopical examination made: (*a*) after several days at room temperature; (*b*) after twenty-three hours at 160 deg. Cent.; (*c*) after thirty days at 200 deg. Cent. No visual evidence of diffusion in depth was obtained from these tests, but photographs showed that very intimate contact was achieved between the components of a joint.

Simultaneously with the metallographic investigation, a radio-chemical approach was pursued. This involved the use of activated wire, obtained by irradiation of commercial tinned-copper wire in the Harwell atomic reactor "Bepo." Sample bound joints were prepared using the radioactive wire as the component wire. Some wrapped joints were also made. After conditioning (up to 200 deg. Cent. for up to 300 hours) these joints were unwrapped and the activity measured. In the bound joint a negligible amount of tin was transferred in the as-made condition, but a considerable amount of transfer had taken place after one hour.

Wrapped joints showed entirely different behaviour, an appreciable amount of transfer occurring in the as-made condition, but this did not increase during heat ageing. These results were broadly substantiated by experiments in which the surface layers were removed in a controlled manner by dissolution in acid, and the solution tested for activity. Some of the testing of solderless wrapped and bound connections was applied to actual equipments incorporating these connections in order to check the overall effect within a unit whose performance was known and established.

Two such units also included several unusual experimental connections, e.g. components with flat lead-out wires were used in bound connections; in other cases, valve fly-leads occupied opposite faces of a single terminal and were bound under one binding wire. Climatic and environmental testing was most severe and caused a number of components to fail or change invalue, but no faults could be attributed to the connections.

Microwaves for Examination of Rotating Bodies

The final session of the conference was concerned with vibration. It included a paper, by P. B. Barber and J. S. T. Looms, on the use of microwaves for the examination of rotating bodies. The profile of a rotating body can be determined from a continuous measurement of the distance between a fixed point and the surface of the rotating member. This distance can be deduced by optical interferometry or reflection measurements or by recording the changes in capacitance between the rotating part and a probe or by the use of microwaves.

A number of advantages over optical and electrical methods are claimed for the use of microwaves involving the detection and measurement of changes in phase or amplitude, or both, in a microwave beam reflected from the rotating part. First, no electrical connection is required to the rotating part. Secondly, it does not matter whether the material of the rotator is conducting or non-conducting provided that its permittivity differs from that of the surrounding medium. Thirdly, the aperture required in the housing need only be small and can easily be made pressure-tight and can be located at any point convenient for the entry of the waveguide. The main difficulty lies in the complexity of the reflected signal except when the rotator has a simple cylindrical or planar form. With rotators of more complex forms quantitative observations are impracticable; with the simpler forms the accuracy of the results is limited by the cost of obtaining sources of waves much shorter than 8mm.

Qualitative Methods.—For qualitative work the simplest system consists of a klystron oscillator which "illuminates" the rotator through a waveguide which carries a stub and a "T"-junction leading to a detector crystal. A signal (which is the vector sum of a direct component from the klystron and of reflected components from the stub, waveguide-end and rotator) is detected by the crystal and the amplified envelope is applied as a radial deflection to the circular time-sweep of an oscillograph. The sweep is synchronised with the rotator and a stationary trace is therefore obtained, the form of which is related to that of the rotator.

The trace is generally much more complex than the profile because reflected power is obtained from more than one point. The stub may be used to emphasise certain reflections, and some simplification of the trace is also possible by modifying the amplifier bandwidth. Departure from symmetry and changes of profile with angular velocity, e.g. damaged blades on a fan with related mechanical oscillation from imbalance, are, nevertheless, readily recognisable.

Quantitative Methods.—Two methods of quantitative measurement are available: they use, respectively, variations in phase and in amplitude with distance. In the first a narrow parallel beam is used and changes in distance are measured by interference fringes. In the second a divergent beam, in which the radiated power falls off rapidly with distance from the source, is used to measure distance in terms of the reflected intensity.

The first method is applicable to long distances but requires a source of relatively large aperture to launch a parallel beam. Although indication is independent of the nature of the reflector, the method suffers from the disadvantage (which is inherent in all interferometers) that ambiguous indication is obtained when the reflector moves through more than $\lambda/2$.

The second method uses a shaped source to produce a polar lobe of the required shape. Dielectric wedges have been used for this purpose. The klystron requires to be protected against "pulling" due to fluctuations in the load presented to it, by means of a pad or ferrite isolator, and a directional coupler replaces the "T"-junction. At 8mm wavelength, sensitivity to changes of 0·01mm is readily obtainable without ambiguity, but limitations are encountered similar to those which are inherent in the use of the capacitance probe.

Conclusions.—1. A microwave system may be used to examine the profile of a rotating body which is inaccessible to optical or electrical observation.

2. Qualitative changes in bodies, even of complex shape such as fans and turbines, are readily detectible as changes in a stationary circular trace which is synchronised to the rotation of the body.

3. Quantitative measurements of variations in bodies of simple cylindrical or planar form are possible, but such measurements are limited in scope.

4. Improvement in the microwave system is likely to result when sources of waves shorter than 8mm become available commercially.

Anti-Vibration Materials

A method of assessing the performance of anti-vibration materials was described in a paper by C. M. Brownsey. He pointed out that structure-borne vibration can be considerably damped by the use of properly designed resilient mountings including commercially available products intended for installation as point supports. But where it is impossible or inconvenient to use point supports materials in sheet form can be used for anti-vibration mountings. In most cases, however, little information is available about the dynamic properties of these materials in the frequency range of 50 to 1000 c/s. To make good this deficiency the paper described a simple method of determining the attenuation to be expected from sheet materials over this frequency range. The apparatus which was designed for making measurements on small specimens, consisted of a vibrating table weighing 8 lb and carrying a 70 lb mass on a sheet of the resilient material.

"Dancing" Conductors on Overhead Lines

The problem of conductor "dancing" on overhead transmission lines was discussed in a paper by T. R. Warren and G. S. Wilton, who gave details of operating experience on the Clyde's Mill—Harker 275kV overhead line which runs between Glasgow and Carlisle across hilly and exposed country in the south-west of Scotland. The line is of double-circuit construction on steel towers and each circuit comprises three twin conductors arranged in almost vertical formation. Since the line was energised in 1954, conductor "dancing" has caused twenty-eight faults between phases during winter gales. With a view to eliminating these costly failures, the South of Scotland Electricity Board has instituted a programme of research into the problem.

Meteorological information, giving a general indication of conditions in the area, has been collected from weather stations nearest to the fault locations as these were discovered. Patrols were sent out when warnings of weather likely to cause clashing were received, and in one instance clashing was observed and a sketch was made of the conductor motion. A study has been made of each faulty section, in profile and in plan, and of the ground topography.

As faults were located, the sections of line affected were fitted with inverted-V semi-tension insulator sets in order to add damping by increased mass and prevent the transmission of travelling waves by the insertion of a stiffened section. The inverted semi-tension insulators proved to have a damping effect in the spans in which they were fitted, since no further faults have arisen there, and the process of fitting them has been continued.

From the first, fault location proved very difficult and necessitated bosun's-chair patrols along the conductors. Although the damage was serious, it was impossible to see from ground level. To solve this problem experiments were undertaken with the Ferranti electrical-pulse echo system of fault location. During the winter of 1960/61, it was possible, with the help of this instrument, to locate faults to within a few spans on the 85-mile line. Whenever gales are forecast by the Weather Office, the instrument is monitored and when conductor movement becomes evident on the cathode-ray tube display screen, engineers can be despatched to the indicated location to observe and record site conditions.

To obtain further data on the forces produced by conductor oscillations, dynamometers and strain gauges are to be fitted to insulator sets. It is also proposed to install anemometers on the line towers in order to obtain more accurate records of wind conditions during faults. Further research into conductor oscillation and methods of damping it is to be carried out in conjunction with the Central Electricity Research Laboratories at Leatherhead and it is proposed to erect an experimental line on an exposed site parallel to the 275kV line. The test line will be equipped for the measurement of wind forces, stresses in conductors and tower members, and for photography of conductor movement.

Aeronautical Research in Australia

The Aeronautical Research Laboratories of the Department of Supply at Melbourne have now published their Annual Report for 1959–60. *The following compilation of results of interest beyond defence requirements is composed largely of abstracts from the Report.*

AMONG other strictly aeronautical work, was the Avro 707A delta research aircraft provided with extra instrumentation to allow a better appreciation to be made of the handling characteristics in the two different flow regimes, labelled "high" and "low" drag. A quarter-scale model was tested in a low speed wind tunnel to investigate the flow separation near the wing tip with a view to preventing hysteresis and if possible to delay the inboard spread of separation.

In the investigation of the reasons for the existence of the two states, differing drag conditions have been found at lift coefficients as low as 0·2 with varying induced drag coefficients. This is thought to be due to wing surface conditions as the wings had been resurfaced after the last flight programme was completed. Large values of outwash (10 deg.) have been measured ahead of the wing tip, and changes of this outwash angle correlate with change of separation pattern as indicated by selected spanwise pressure-plotting.

The final measurements have now been made in the wing tip extension tube project (see page 1056, December 23, 1960) and no further work is mentioned.

Continuing the investigation of a 5 per cent biconvex delta wing of aspect ratio one, an examination has been made of the flow in the boundary layer at a number of stations over the surface and at incidences up to 50 deg. A hot wire traversing head was used. A most interesting finding is that a considerable area of laminar flow exists over the forward inboard part of the upper surface at incidences above about 18 deg. when the outflow induced by the leading edge vortices extends from the root section (Fig. 1). At lower incidences, when a streamwise flow attaches to the surface inboard of the vortices, the boundary layer is turbulent.

The emphasis on fatigue has been sustained, and the test on the wing of a de Havilland "Dove" using programmed loading at a resonant frequency of 500 cycles per minute has progressed. So far the wing has been loaded to the equivalent of 40,000 hours, being about 60 per cent of the proposed test life. Some cracks have been detected radiographically and have been repaired. Aluminium alloy centre-section booms of the type which failed in service have been used. Two of these failed, one at

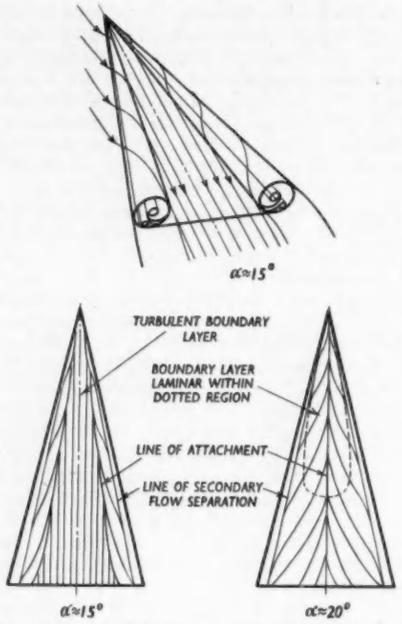


Fig. 1—Flow over a delta wing of unity aspect ratio with a five per cent t/c biconvex section

the equivalent of 10,000 flying hours and the other at 15,000 hours. These lives, being in good agreement with the original estimate and with the service failure at 9000 hours, suggest that the programmed loading chosen is a good simulation of actual flight conditions.

The possibility of improving the fatigue life of aluminium alloy wing spars (beams) by pre-stressing the tension flange with steel was investigated. It was shown that, if local instability is not critical, a beam of ultra high strength steel (280,000 lb per square inch ultimate) is the lightest for given life and load conditions. Alternatively, a steel beam will have about thirty times the fatigue life of a 75-ST aluminium alloy beam of the same weight. A prestressed composite beam of the same two materials is intermediate in properties and a life ten times that of the plain 75-ST beam could easily be achieved. However, the manufacturing difficulties are most formidable for both the composite beam and the ultra high strength steel beam.

Alloys based on the aluminium-zinc-magnesium (Al-Zn-Mg) system have very high static strength properties which have led to their wide application as materials for aircraft construction. For this purpose, however, the alloys have three disadvantages, namely, a tendency to stress-corrosion cracking, a relatively low ratio of fatigue strength to ultimate tensile strength, and a tendency for sheet to shatter under ballastic impact. At A.R.L., it is considered that these problems are intimately associated with the structure of the alloys formed during the age-hardening process. For this reason, a study of ageing phenomena in a large range of related alloys was undertaken.

Early work showed that quite small additions (less than 0·1 atomic per cent) of silver exerted a marked beneficial effect on the ageing processes of the basic high-purity ternary Al-Zn-Mg alloys aged in the medium temperature range (120 deg. to 220 deg. Cent.). Electron microscopy has revealed that silver may facilitate formation of a fine precipitate which is very evenly dispersed, particularly in the region of the grain boundaries. The presence of this fine precipitate increases the capacity for age-hardening at these temperatures so that a higher ageing temperature may be used. Both these factors should increase the resistance of the alloys to stress-corrosion cracking and this has been established for high purity materials.

A laboratory scale evaluation has continued into the effects of adding silver to the actual commercial materials 7079,7178, and notably D.T.D.683. Previous indications that the influence of silver is not reduced by the presence of impurities and other alloying elements have been confirmed. However, limitations on the production of suitable materials and in testing facilities have not permitted a study of the stress-corrosion properties of these materials. Minor improvements in fatigue properties and behaviour of the silver-containing alloys at elevated temperatures have been recorded. It has been shown that the effects of silver are little altered by cold work before ageing but may be sensitive to the rate of quenching.

Of theoretical interest is the mechanism by which such small amounts of silver may exert the observed marked effects in the alloys. It is apparent that silver facilitates nucleation of the phase formed on ageing the alloys in the medium temperature range. Present results suggest that this phase is the intermediate form of Mg Zn_2, and that the effect of silver is specific only to this phase. This result is significant in relation to trace effects in other age-hardening alloys and a detailed study is being made of the mechanism involved.

Relatively little work has been done on the practical aspects of a second project in

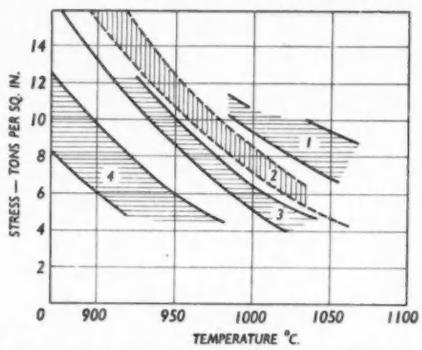


Fig. 2—100-hour rupture strength : (1) A.R.L./D.S.L. wrought chromium alloys ; (2) Best cast nickel-base alloys ; (3) Best wrought nickel-base alloys ; (4) Wrought nickel-base alloys widely used in current engines

which an attempt is being made to design a fatigue-resistant alloy based on the Al-Zn-Mg system. However, arrangements have been made with the Department of Mines and Technical Surveys, Canada, for the production of some extruded bar in the several experimental alloys.

The parallel metallographic study of deformation occurring in the interior of fatigued Al-Zn-Mg alloy specimens has continued. Particular attention is being directed to two phenomena associated with the concentration of stress in certain slip band regions, i.e., the generation of small cavities in slip bands, and the formation of regions depleted of precipitate. This latter effect is attributed to the resolution of the precipitate rather than the earlier idea of localised over-ageing.

An investigation is being made of the effects of various residual stress systems on the stress-corrosion behaviour of aircraft alloys. In the case of heat-treated aluminium alloy D.T.D.687, it has been found that the threshold level of stress above which the material will fail rapidly in a corrosive environment is in the region of 102 per cent of the 0·1 per cent proof stress. A second series of heat-treated D.T.D.687 specimens was strained to a permanent elongation of 1·75 per cent before test, this being sufficient impose microstresses in the test section with low or insignificant macrostresses. The resulting stress-corrosion properties were superior to those of the unstretched sheet.

In collaboration with Dr. J. E. O. Mayne, of Cambridge University, a new theory of corrosion of metals has been put forward which states that, in the absence of anions which are more readily polarisable than the hydroxyl ion, the occurrence or otherwise of corrosion depends on the relative strengths of two competing effects : (i) the dissolution of the air-formed oxide film, and (ii) the building up of the anodically formed oxide film, in the particular aqueous environment under investigation.

The theory has been tested experimentally with aluminium, iron and zinc in a variety of corrosive media, with results which strongly support the above postulates. One finding of special interest is that aluminium will not corrode in solutions which are already saturated with aluminium oxide. This is in agreement with the theory, and suggests new methods for protecting this metal in certain applications.

On a laboratory scale, Materials Division has developed ductile chromium alloys which exhibit more than adequate strength for use as rotor blading in turbojet engines operating at temperatures in excess of those encountered in current practice. This has involved a comprehensive study of the relevant properties such as creep strength, room-temperature ductility and oxidation resistance. However, the ultimate test of the materials must be their performance when fabricated into blades and run under under realistic engine operating conditions.

A rig turbine has been designed to operate at a gas temperature of 1400 deg. K., to determine the behaviour of the new alloys. This unit is now being manufactured. Some novel design problems were encountered, particularly the cooling of the stator row, which was to be fabricated from sheet metal and air-cooled, and the inlet cone fairing which would be subjected to the highest gas temperatures together with radiation from the combustor supplying the rig with hot gas.

Rig experiments have been carried out to evolve a satisfactory method of air cooling the stator row and conical fairing. The difficulty in air cooling hollow blades lies mainly in cooling the thin trailing edge. This has been accomplished by inserting a strip of copper which conducted heat readily into a region swept by internal cooling air flow. The conical fairing was adequately cooled by impinging jets of air from a

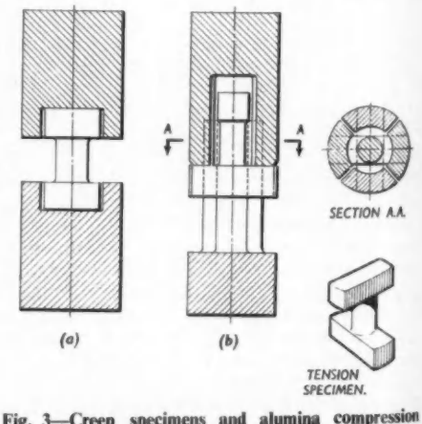


Fig. 3—Creep specimens and alumina compression rams, arranged (a) in compression, (b) in tension

perforated liner against the inner surface.

Closer attention has been paid to high-strength chromium alloys containing metals other than tungsten as the principal addition, e.g., molybdenum and tantalum. This change has given a desirable reduction in the density of the alloys and at the same time resulted in some of the strongest hot-workable compositions yet produced in the project. They compare more than favourably with the best nickel-base alloys available (Fig. 2).

Unlike the chromium-tungsten compositions, most of these newer alloys depend strongly on precipitation-hardening for their high-temperature strength. This has necessitated additional phase-diagram studies, and an accurate determination of the solid solubility of tantalum in chromium is nearing completion.

Trial melts with sprayed alumina mould liners (prepared by the Weapons Research Establishment) have shown some refinement of the coarse ingot structure of high-strength alloys, but have not eliminated sporadic ingot cracking. Further work is projected with thicker alumina coatings. One useful development in hot working was the successful extrusion of a high-strength alloy in a section having one dimension larger than the diameter of the starting ingot. It was also confirmed that press forging was much facilitated by the use of heated platens. Certain of the alloys have shown a susceptibility to grinding cracks, and the separate effects of the numerous grinding variables are being systematically investigated in conjunction with the Workshops. The results are evaluated by means of microscopic examination and X-ray determination of surface stresses.

With certain alloys it has been found that the compression creep test gives results which are not concordant with tensile creep results. This limits its value for preliminary "sorting" and two of the three compression machines have therefore been converted to tensile loading. The main feature of the conversion is the simplicity of the unique loading arrangement (Fig. 3), which makes it potentially useful up to very high test temperatures.

An investigation has been made into the effect of strain rate on the ductility of rolled chromium strip. It was found that the ductile-to-brittle transition temperature in bending increased from −45 deg. Cent. to +40 deg. Cent. as the strain rate increased from 2×10^{-3} to 2in per minute. From these results it is predicted that the transition temperature under impact conditions would be 200 deg. to 250 deg. Cent. Other work on the ductility of pure chromium has included the development of a microfocus X-ray technique for detecting small strains in test specimens, and has shown that the beneficial effect of pre-straining on ductility is retained even after high-temperature annealing.

Notable progress has been made in improving the ductility of high-strength alloys, one of which has been produced in a form which gives 25 per cent tensile elongation at room temperature and ductility in slow bending down to −120 deg. Cent. The low-temperature result is actually better than can be obtained with pure chromium, and is due mainly to the effect of scavenging additions. However, prolonged heating in air at temperatures above 1000 deg. Cent. causes a rise in the ductile-to-brittle transition to 430 deg. Cent. and this problem of service embrittlement remains to be solved.

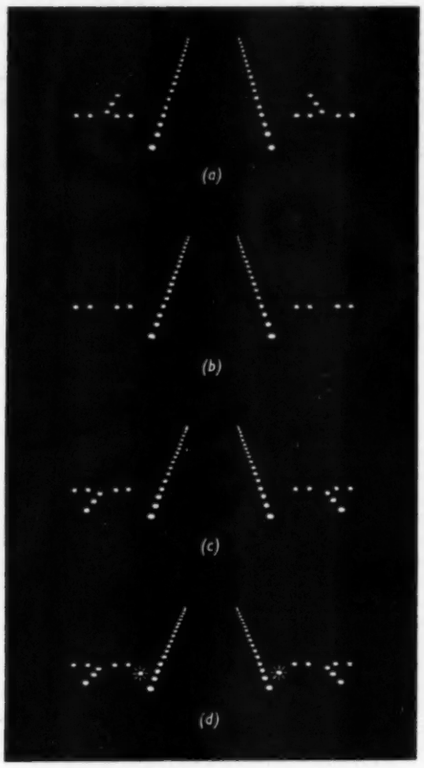
Oxidation studies have continued in the micro-balance equipment, and have been supplemented by simulation tests in a turbine combustor rig at temperatures in the region of 1040 deg. Cent. The rig conditions closely parallel those occurring in an engine gas stream, and the results obtained to date on chromium alloys with respect to scale adhesion and nitrogen pick-up are very satisfactory. It appears that scaling results obtained in still air may give a conservative picture of the capabilities of chromium alloys in a fast gas stream.

A comparative evaluation of fouling has been made with chromium-based alloys and with a typical nickel-based turbine blade alloy in the exhaust of a combustor using vanadium-bearing fuel oil. A small turbine with mixed blading was used for initial testing but the small blade size hindered accurate evaluation. Tests with a static cascade of mixed blades of a larger size have shown that whereas the nickel-based alloys suffered considerable intergranular penetration by vanadium pentoxide, the chromium blades were unaffected. In addition, there is evidence of concentrated vanadium attack on specific areas of the nickel alloy blades, which may shed light on the deposition mechanism involved.

After a preliminary functioning test the Ruston and Hornsby "TA" (1400 h.p.) turbine has been operated for two runs of nine-and-a-half and twenty hours respectively on brown coal. Turbine inlet temperature was held at 650 deg. Cent. and the runs were uneventful apart from slight trouble arising from condensation of water from the coal in the filter system.

A subsequent stripping-down of the engine showed that considerable erosion had occurred in stator and rotor blading; this was quite unexpected as deposition had proved the greater difficulty both in the running of a small engine and in rigs set up for examining the effects of ash in the gas.

The position was not improved by increasing the fineness of coal fed to the combustor. It is now considered imperative to fit an ash separator between combustor and turbine, although experiments are being carried out and are planned to check the effect of further fining down the coal. This will be done by finer grinding and by inserting in the coal feed to the combustor a classifier designed to give a sharp size-cut.



(a) Too High. (c) Too low.
(b) On glide path. (d) "Wave off."

Fig. 5—"Tee" system as seen on landing approach

Tests have been made with two combustors in which the whole of the airflow is given a maximum amount of swirl via a louvred flame tube. With volatile fuel this results in an intense and stable flame with excellent wall-cooling. With solid fuels, such as pulverised brown coal, larger particles are centrifuged outside the flame zone and are ejected at the rim of the outlet. If these are drawn off the burner acts as its own classifier.

One means of improving combustion efficiency is by increasing the residence time of burning coal particles by arranging for combustion air to enter the flame tube of the combustor with tangential swirl. This increases the path length of the coal particles. Combustion in a flame tube of this design appears excellent, but accumulation of sooty deposits on the entry cone of the flame tube gives rise to combustion losses.

A simplified atmospheric combustor for low temperature rise has been evolved, and should be suitable for oil-fired kilns or driers. The normal flame tube has been eliminated and combustion is concentrated behind a simple conical baffle placed concentrically in a circular section duct. The recirculation behind the baffle is stabilised and strengthened by a deflector causing radial inflow a

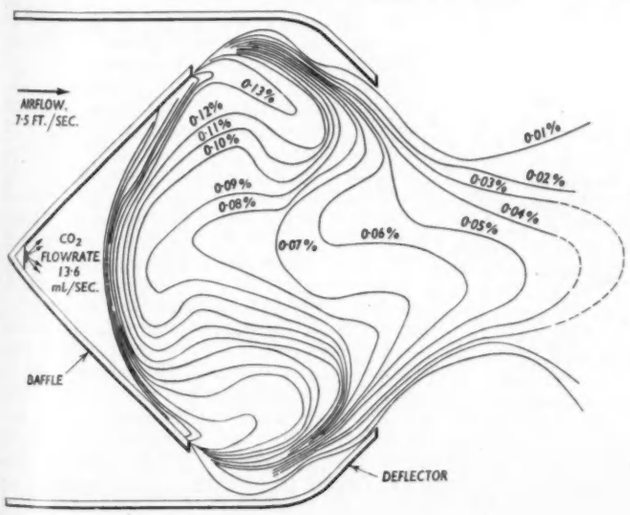


Fig. 4—Mixing pattern in a simple baffle combustor, as shown by CO_2 tracer concentration

short distance downstream of the baffle. This configuration has been derived from a theoretical and experimental study of the flow behind baffles. (For example see Fig. 4.) Promising results have been obtained with a ring of small peripheral atomisers directed into this zone from the wall of the containing duct, giving clean smoke-free combustion. The great advantages of this combustor are its extreme simplicity, and its freedom from coking and other troubles arising from the conventional flame tube.

A feature of the combustor is its great reliability with combustion intensities higher than normal in heavy oil burning gas turbines.

The oxygen lance that has been discussed for some years has not yet proceeded to flight testing. Experience has shown that in gas turbine aero engines flame-out can occur under the combined pressure disturbance and water ingestion which follow breakaway of ice accretions in the intake ducting. Tests in a rig simulating these conditions have shown that continuous injection of oxygen at a low rate is a satisfactory alternative method to using a glow plug as a means of preventing flame-out.

At the request of Bristol-Siddeley Engines, Ltd., an experimental programme has been carried out to assess the effects of oxygen injection into the combustion chamber of a typical Bristol design of ram jet. The oxygen injection arrangements were similar to those previously developed for the "Avon" combustor, and measurements of ignition and stability limits have been made over a range of pressures and temperatures from 2·2 lb per square inch absolute, −20 deg. Cent. (corresponding to high altitude low speed operation) to 14·0 lb per square inch absolute +180 deg. Cent. (corresponding to high speed operation). The attainment of these operating conditions, particularly that of low temperature, presented considerable local difficulty in the rig design. Eventually a Hilsch vortex tube was used to attain the desired low temperatures. Ignition and stability limits are greatly extended when oxygen is used, allowing operation at pressures (and hence altitudes) unattainable without the use of oxygen. It is also proposed to measure the improvement in combustion efficiency due to oxygen injection.

The work on human engineering has continued to be devoted extensively to the problems of approach and landing. Basic research at the University of Sydney into the visual judgments made by the pilot seems to indicate that the human judgment of the centre of expansion of an expanding pattern on the retina of the eye is very poor. However, the judgment of the apparent motion of some particular point in the field of view is much better. This suggests that the pilot may make his judgments mainly by assessing the apparent motion of prominent objects, such as the runway threshold.

The evolution of visual approach guidance systems has progressed. A system which is claimed to have none of the disadvantages of the Precision Visual Glidepath, in which the pilot aligns two bars of light on the ground, and the Visual Glidepath Indicator, in which the lights on the ground change from white to red if the pilot departs from the glidepath, has been designated the "Tee" Visual Glidepath; Fig. 5 shows that it is an "appearance" presentation somewhat similar to the deck-landing projector sight recently developed in Great Britain (see page 432, September 15, 1961).

Tests were conducted in December (1959) in conjunction with the University of Sydney on two simple altimeter modifications developed by Trans-Australia Airlines and A.R.L. The test observers, who were all pilots, were required to read the altimeter while busily engaged in flying a complex pattern in the Link trainer, and 12 per cent of all readings were found to be in error by more than 1000ft. The differences between pilot performance on the standard three-pointer altimeter and the two modified instruments were small, and statistical significance could not be achieved with the limited number of pilots available. Both domestic air lines have requested further tests of a similar type on new displays they have developed.

Exploratory tests were carried out to aid the Standards Association of Australia (S.A.A.) compile a specification for car seat belts. Some of the tests included the determination of the release forces which could be exerted by individuals. Whereas overseas specifications allowed a maximum force of 45 lb, these tests showed that only 60 per cent of males and 20 per cent of females could exert this force, and so the Australian requirement was set at 25 lb. A number of A.R.L. recommendations have been adopted in the latest S.A.A. draft. Many makes of seat belts have been submitted for test against the full requirements of the proposed specification.

A prototype vibration isolating mounting was designed and made following a scheme proposed by Molyneux (page 1065, June 30, 1961) of the Royal Aircraft Establishment. He showed in a theoretical paper that if an axial spring supporting a load is combined with transverse springs in the correct stiffness and geometrical ratios, the result is a spring system which effectively has zero stiffness at the design deflection while continuing to support the design load. Such a device has great potential usefulness for isolating the load from vibration, particularly at low frequencies where conventional mountings transmit most of the applied amplitudes.

The first version was designed to support a weight of 3½ lb and consisted of an axial coil spring in association with a symmetrical arrangement of six transverse leaf springs in bending in the manner of Fig. 6. After some initial difficulties were overcome, the device exhibited the force deflection characteristic shown in Fig. 7. Zero stiffness is confirmed by the slope of the curve at the design point. The mounting was fixed to the moving platform of a vibration calibrator and demonstrated a spectacular reduction of vibration with relatively large applied amplitudes even at low frequencies (down to 5 c.p.s. or less). On the basis of this initial test, it is intended to apply the scheme to the mounting of the sighting head of a service bombsight.

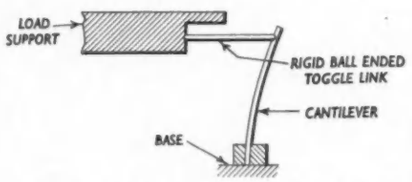


Fig. 6—Disposition of leaf spring in non-linear spring support

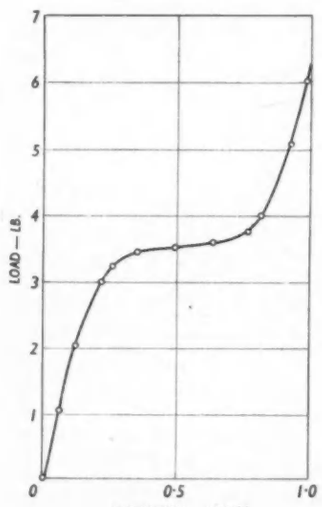


Fig. 7 — Force/deflection characteristic of zero stiffness anti-vibration mounting

An optical display unit capable of simulating the instantaneous position and apparent size of a moving object having components of motion on three planes, has been developed as an aid to the study of control and guidance systems. The unit consists essentially of a light source and a mirror which is gimbal-mounted to permit rotation about two axes. The mirror deflects a light beam to form an image on the inside surface of a hemispherical enclosure. Two position servos control the rotation of the mirror and so determine the position of the image, and a third servo controls the size of the light aperture, and hence the size of the image. Air lubrication is used in the main bearings to reduce static friction to a minimum.

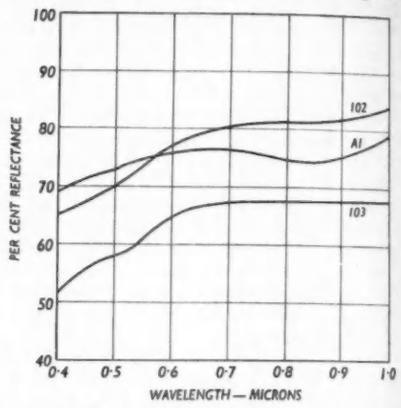


Fig. 8—Special reflectance of two paint samples (102 and 103) compared with polished aluminium (Al)

Air bearings have been used also in a unit designed for the measurement of static and dynamic friction torque of precious metal slip rings and brushes and of other low-friction devices, while the near-frictionless properties of air lubrication have been utilised in a bearing to support models during wind tunnel tests.

A range of transducers suitable for general use and with sufficient electrical output to operate a recording oscillograph without amplification was required. Consequently, a design was adopted in which pressure applied inside a beryllium copper tube with elliptical cross-section produces compressive strains at the ends of the major axis and tensile strains at the ends of the minor axis. These strains are sensed by bonded resistance strain gauges, and cause an unbalance voltage to appear in a bridge circuit. Subsequently it has been learnt that this type of pressure transducer had been evolved independently at the Royal Aircraft Establishment but not exploited commercially. Performance features include an output of 10 millivolts, linearity better than ¼ per cent of full scale, hysteresis less than ½ per cent and frequency response estimated at 5 kc/s. Full scale ranges of the transducers can vary from 0 to 10 lb per square inch to 0 to

10,000 lb per square inch according to the thickness and material of the tube.

The measurement of the physical properties of electric resistance strain gauges continued, one new facet being the study of the properties of Eastman 910 adhesive for attaching strain gauges. This pressure sensitive adhesive has been found to be superior to commonly used cements in that it needs no curing and that a gauge can be used within minutes of it being pressed on to the surface. It has also been found possible to release and re-use the more robust gauges by heating the adhesive for a period at about 120 deg. Cent. The only two known materials to which it has not been possible to make it adhere are polythene and "Teflon."

Australia, Canada and the United Kingdom are collaborating on thermal insulation of the outer surface of high-speed aircraft: co-ordination is being effected with the aid of the Commonwealth Advisory Aeronautical Research Council. A.R.L. is investigating paints capable of reflecting solar radiation yet having high total emittance (more than 80 per cent) at 400 deg. Cent.

The requirement for such a paint was that it should have high reflectance for solar radiation in the wavelength range 0·3–2 microns and high absorptance for the infrared wavelengths (3 to 20 microns) corresponding to black-body emission at 400 deg. Cent. The service life required was several hundred hours at 400 deg. Cent. Consideration of optical scattering processes indicated that the size of the pigment particles should be about 2 microns, while a survey of absorption spectra and high-temperature properties suggested that quartz would be a suitable pigment material and silicone resin a satisfactory vehicle.

Paints of this type, made in these Laboratories, have shown fully satisfactory optical properties. Thus, the total emittance at 400 deg. Cent. has been found to be approximately 90 per cent., i.e., comparable to a carbon black deposit. At lower wavelengths of 0·4 to 1·0 microns, spectral reflectance measurements (made at the Defence Standards Laboratories) gave values in the region 65 to 80 per cent, which are comparable to industrially polished aluminium sheet (Fig. 8). Consideration will now be given to more accurate measurements of emittance and to tests of appropriate mechanical and cohesive properties.

Dynamic Behaviour of Pneumatic Gauging Systems*

By I. G. MORGAN, M.A. and JULIA B. JOHNSON, B.Sc.

The response of a simple pneumatic gauging system to a periodic input of variable amplitude and frequency is studied theoretically and experimentally. It is shown that the best response is obtained using a low operating pressure, a low sensitivity and a small circuit volume. A comparison of theoretical and experimental results shows that the theory, though very much simplified, is a reliable means of predicting dynamic behaviour.

WHEN the pneumatic gauging technique is used in continuous measurement, in automatic inspection equipment or for control of machine tools, the dynamic response characteristics of the measuring system may have an important effect on performance. The requirements for good response characteristics are generally understood in a qualitative sense but little quantitative data is available as a positive basis for design. With this in mind an investigation has been undertaken at the National Physical Laboratory and the present paper reports the results of a preliminary series of experiments. These relate to somewhat idealised systems and are intended to provide information on general behaviour to serve as a guide in the design of such further experiments on more complex systems as may seem desirable.

The Scope of the Experiments

Fig. 1 shows schematically a pneumatic measuring system in which the indicator is responsive to displacements of the surface towards or away from the nozzle. (The basic principles of the pneumatic technique have been fully described elsewhere.[1–5])

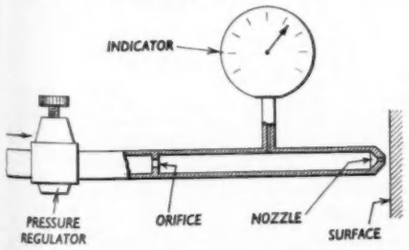


Fig. 1

The speed of response of the indicator pointer to displacements of the surface will depend on factors which can be classified in broad terms as follows :

(*a*) The constant operating pressure delivered by the regulator.

(*b*) The restriction to flow imposed by the orifice and nozzle. This will depend primarily on the escapement areas of the orifice and nozzle and will govern the static sensitivity of the system.

(*c*) The volume of the connecting pipe between the orifice and the nozzle.

(*d*) The volume and restrictive effect of the pressure connection to the indicator.

(*e*) The response characteristics of the indicator.

In practice the simple system illustrated in Fig. 1 takes many forms and there is particular variety in the type of indicator used and the nature (e.g. the length) of the pressure connection to it. The response characteristics of the indicator will be imposed upon the characteristics of the remainder of the system and as different types of indicators may have markedly different response characteristics it would be difficult to draw conclusions of general applicability from experiments on any particular arrangement. For this reason it was decided to conduct preliminary experiments on the orifice/nozzle part of the system only, measuring as directly as possible, and with a special instrument having a response very fast in relation to the response of the pneumatic circuit, the pressure changes in the volume enclosed between the orifice and nozzle with no conventional pressure indicator attached. This was done using a small pressure transducer of electrical capacitance type as described later. The results of these measurements are of immediate interest as they show the behaviour of the primary pressure changes in the system. They also serve as a foundation for further investigation, both of the effects of transmitting these changes over a given distance to an indicator of particular type and of the manner in which the primary changes may be modified by the presence of such an indicator.

The experiments were carried out by applying sinusoidal oscillations of variable frequency and amplitude to the surface shown in Fig. 1. Several different sizes of orifice and nozzle were used in combination with different values of the volume between the orifice and nozzle and different values of the constant operating pressure. In each instance, for a given amplitude of oscillation of the surface, a record was obtained relating the amplitude of the pressure changes to the frequency of oscillation.

Some Theoretical Considerations

A theoretical analysis of the behaviour of even the simplest system becomes complex if any attempt at a rigorous treatment is made. However, a much simplified and approximate treatment indicates the behaviour to be expected and one object of the present work has been to establish the degree of usefulness of the following elementary analysis.

At time t let

Q_o = Rate of flow of air through the orifice (mass units per second).

Q_n = Rate of flow of air through the nozzle (mass units per second).

and

M_v = Mass of air contained in the volume between orifice and nozzle.

Then,

$$d/dt(M_v) = Q_o - Q_n \quad . \quad . \quad . \quad \text{(i)}$$

To obtain a solution of Equation (i) describing the pressure in the system as a function of time we require to express : Q_o, Q_n and M_v in terms of pressure.

Assuming that the flow through the orifice is adiabatic the following expression can be derived from Bernouilli's Theorem.

$$Q_o = c_o a_o \{2g\gamma/(\gamma-1) \cdot \rho_1 p_1^{(\gamma-2)/\gamma} \cdot p_2^{2/\gamma} [1 - p_2/p_1)^{(\gamma-1)/\gamma}]\}^{\frac{1}{2}} \quad . \quad \text{(ii)}$$

where,

c_o is a coefficient of discharge for the orifice.

a_o is the area of the orifice.

g is the acceleration due to gravity.

γ is the ratio of specific heats of air.

ρ_1 is the density of air under the conditions upstream of the orifice.

p_1 is the absolute pressure upstream of the orifice.

p_2 is the absolute pressure downstream of the orifice.

This expression (and the corresponding expression for Q_n) is too cumbersome for convenient solution of Equation (i). However, by using Equation (ii) to compute tables of values of Q_o (and the corresponding equation to evaluate Q_n) for various values of p_1 and p_2 we can derive simpler approximate relationships which fit these values over restricted ranges of pressure. Such relationships, expressed for convenience in terms of gauge pressures, can be obtained in the form,

$$Q_o = c_o k_n a_o (P - p^x) \quad . \quad . \quad . \quad \text{(iii)}$$

$$Q_n = c_n k_n a_n (p)^\beta \quad . \quad . \quad . \quad . \quad \text{(iv)}$$

* Communication from the National Physical Laboratory.

where,

c_o and c_n are coefficients of discharge.

k_o, k_n, α and β are constants for given pressure ranges.

a_o and a_n are the escapement areas of orifice and nozzle respectively.

P is the gauge pressure upstream of the orifice.

p is the gauge pressure in the volume between orifice and nozzle.

It is to be noted that by using a common value of p in both expression (iii) and (iv) we assume that there is no pressure gradient between the orifice and the nozzle, i.e. that the effects of inertia and viscosity of the air, and any restriction to flow imposed by the connecting pipe, are negligible.

Experience suggests that, in the circumstances usually encountered in practice, conditions in the volume between the orifice and the nozzle can be treated as isothermal. Making this assumption we can write

$$M_v = k_v V(p+\Pi) \quad . \quad . \quad . \quad . \quad . \quad (v)$$

where,

k_v is a constant for given conditions.

V is the volume between orifice and nozzle.

Π is atmospheric pressure.

Substituting in (i) from (iii), (iv) and (v) gives

$$k_v V dp/dt = c_o k_o a_o (P-p)^{\alpha} - c_n k_n a_n p^{\beta} \quad . \quad (vi)$$

If a_n is a function of time, say, $a_n = \bar{a}_n(1+b\sin\omega t)$ we may write,

$$dp/dt = A(P-p)^{\alpha} - Bp^{\beta}(1+b\sin\omega t) \quad . \quad (vii)$$

where,

$$A = c_o k_o a_o / k_v V \text{ and } B = c_n k_n \bar{a}_n / k_v V$$

If we consider small values of b giving rise to small changes of p about a mean value denoted by $\bar{p}$ and write $p = \bar{p} + z$, where z is small, Equation (vii) reduces to

$$dz/dt + Kz = -B\bar{p}^{\beta} b\sin\omega t \quad . \quad . \quad (viii)$$

where,

$$K = B\bar{p}^{\beta}\{\alpha/(P-\bar{p}) + \beta/\bar{p}\} = A(P-\bar{p})^{\alpha}\{\alpha/(P-\bar{p}) + \beta/\bar{p}\}$$

Equation (viii) is a standard form with solution

$$z = -B\bar{p}b/(\omega^2+K^2)^{\frac{1}{2}} \sin(\omega t + r), \text{ where } \tan r = -\omega/k$$

If we denote by R the ratio of the amplitude at any frequency to the "static" amplitude ($\omega = O$) we have

$$R = \left(\frac{1}{1+\omega^2/k^2}\right)^{\frac{1}{2}}$$

For any given value of ω the value of R decreases as K decreases. To examine the influence of the individual circuit parameters we can reduce the expressions for K by putting in numerical values. Values for k_o, k_n, α and β are shown in Table I. These

TABLE I

P	k_o	α	k_n	β
40 lbf per square inch ...	0·450	0·350	0·112	0·655
20 lbf per square inch ...	0·313	0·385	0·183	0·490
5 lbf per square inch ...	0·207	0·455	0·183	0·490
1 lbf per square inch ...	0·185	0·490	0·183	0·495

are calculated for the pressure range $p = 0{\cdot}6P$ to $p = 0{\cdot}8P$, i.e. $\bar{p} = 0{\cdot}7P$. (This condition is frequently used in practice).[3]

Substituting in the expressions for K we obtain Table II.

TABLE II

P	K
40 lbf per square inch ...	$0{\cdot}055\frac{c_o a_o}{k_v V}$ or $0{\cdot}065\frac{c_n \bar{a}_n}{k_v V}$
20 lbf per square inch ...	$0{\cdot}060\frac{c_o a_o}{k_v V}$ or $0{\cdot}070\frac{c_n \bar{a}_n}{k_v V}$
5 lbf per square inch ...	$0{\cdot}110\frac{c_o a_o}{k_v V}$ or $0{\cdot}155\frac{c_n \bar{a}_n}{k_v V}$
1 lbf per square inch ...	$0{\cdot}240\frac{c_o a_o}{k_v V}$ or $0{\cdot}360\frac{c_n \bar{a}_n}{k_v V}$

From Table II we see that the value of K, and thus the value of R, for any given frequency decreases if

(i) the constant operating pressure is increased,

or

(ii) the orifice and nozzle escapement areas are decreased, i.e., the sensitivity of the system is increased,

or

(iii) the volume between the orifice and the nozzle is increased.

The physical significance of these results is easily understood. The lower the operating pressure the more closely does the behaviour of the air correspond to that of an incompressible fluid, for which, if friction, viscosity and inertia effects are neglected, there would be no diminution of amplitude with increasing frequency. When the areas of the orifice and nozzle are small the rate of mass flow for any given pressure drop is small and appreciable time is required for a change of mass within the volume, corresponding to a change of pressure, to be established. Thus for small orifices and nozzles, i.e. at high sensitivity, the response deteriorates. The smaller the volume contained between the orifice and the nozzle the smaller is the mass of air which must be introduced into or expelled from this volume in order that a change of pressure may be established, so that a reduction in volume improves response.

The predictions of this simple theory will later be compared with results obtained by experiment.

The Experimental Apparatus

The apparatus is illustrated diagrammatically in Fig. 2. In the block A is a bore, of diameter w and length l, at the ends of which are fixed an orifice B and a nozzle C, both of circular section. Air at the constant operating pressure is supplied to the system by a connection to the screwed plug D which locks the orifice plate in position. In the side of the bore, at a point mid-way between the orifice and the nozzle, an outlet leads to a chamber into which is fitted the pressure transducer. This is an electrical capacitance transducer in which a thin circular membrane E of phosphor-bronze is soldered to the rim of the brass body F. Into the body is screwed a fitting carrying an insulated plate G which can be brought into close proximity with the membrane. E and G thus form the earthed and insulated plates respectively of a parallel plate condenser with an air dielectric. A change of pressure inside the chamber distorts the membrane, so causing a change in the capacitance of the condenser, and this actuates standard recording equipment.† In this equipment the condenser is part of the tuned circuit of an oscillator and changes in capacitance modulate the frequency of oscillation. The resulting signal is passed to a frequency discriminator the output voltage from which is amplified to drive a high-speed pen recorder.

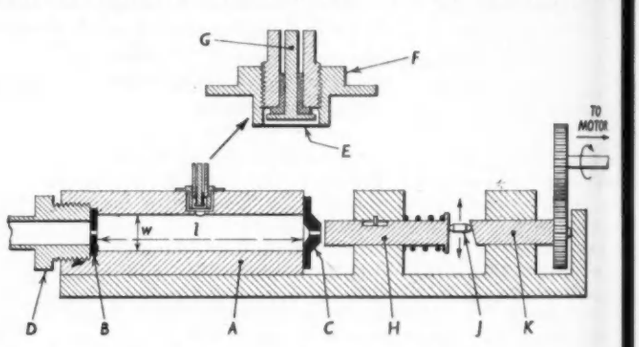


Fig. 2

Air from the nozzle impinges on the end of the plunger H. The plunger, which is free to slide without rotation in its bearing, is forced by a spring against the pin J which, in turn, is forced into contact with the face of the shaft K. The shaft cannot move axially, but is rotated by a variable speed motor. The face against which the pin J bears is machined at a slight angle to the axis so that as the shaft rotates an oscillatory axial motion can be imparted to the plunger H, the amplitude depending on the amount by which the pin is offset from the axis. The pin is actually mounted in a sliding block, which is omitted from the diagram for the sake of clarity, and the offset of the pin is varied by traversing the block in a direction perpendicular to the axis. In the present experiments the amplitude of oscillation could be adjusted in this way from zero (with the pin contacting on the axis) to 0·005in (0·125mm). By adjustment of the motor speed the frequency could be varied from 0 to 30 c/s.

The orifice plates used were of brass of the form shown in Fig. 3 (*a*), the diameter d_o of the centre hole varying according to the sensitivity required from about 0·0193in (0·49mm) to 0·0376in (0·955mm). The proportions of the nozzle are shown in Fig. 3 (*b*). Values of the nozzle diameter d_n of 0·030in (0·75mm), 0·045in (1·125mm) and 0·060in (1·50mm) were used.

The Experimental Procedure

The experimental procedure was planned so as to determine the relationship between the response and the three factors: (*a*) operating pressure; (*b*) sensitivity; and (*c*) volume, on which it depends. However, instead of working directly in terms of sensitivity it was more convenient to use its inverse, the range of displacement corresponding to a selected change of the pressure p. In a pneumatic measuring system the rela-

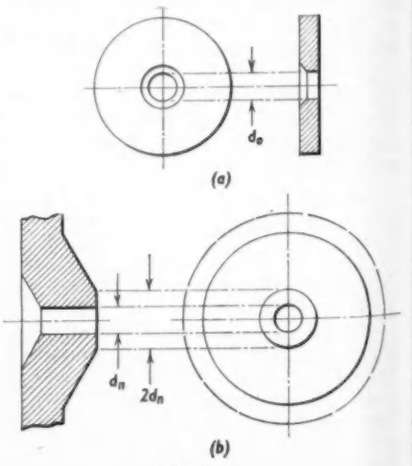


Fig. 3

† Equipment by Southern Instruments Ltd.

tionship between the pressure p and the nozzle escapement is generally linear to within 1 per cent for $0{\cdot}6 < p/P < 0{\cdot}8$[3] and many standard instruments operate over pressure ranges not far removed from this. It was, therefore, decided to use these limits of pressure throughout the experiments and in each test the sensitivity was adjusted so that for a selected amplitude of oscillation of the plunger H (Fig. 2), the pressure values at the limits of displacement corresponded to $p/P = 0{\cdot}6$ and $p/P = 0{\cdot}8$ respectively. (This change of pressure is too large to comply strictly with the assumption of "small changes" in the derivation of the theoretical equation (viii) but it was considered that the experimental results would be, of themselves, of greater value if a larger change were used.)

Four different amplitudes of oscillation were used namely, 0·0005in (0·0125mm), 0·001in (0·025mm), 0·002in (0·05mm) and 0·004in (0·1mm). For each amplitude of oscillation tests were carried out with four values of the constant operating pressure P, namely lbf per square inch (0·07 kgf per square centimetre), 5 lbf per square inch (0·35 kgf per square centimetre), 20 lbf per square inch (1·4 kgf per square centimetre) and 40 lbf per square inch (2·8 kgf per square centimetre). Four values of bore diameter (w in Fig. 2) were used in association with a bore length (l in Fig. 2) of 4in (102mm) thus providing four values of the volume V, namely, 0·27 cubic inch (4·4 cubic centimetre), 0·92 cubic inch (15·1 cubic centimetre), 3·21 cubic inch (52·5 cubic centimetre) and 28·3 cubic inch (464 cubic centimetre).

Before each test, i.e. for each combination of sensitivity, pressure and volume, a static calibration of the recorder pen displacement was carried out, the transducer chamber having a tapping for temporary connection of a pressure gauge. The test itself consisted of running the equipment at a series of frequencies of oscillation from zero upwards, taking a chart recording of the pressure changes at each frequency. From the recordings and the static calibration the amplitude of the pressure changes at any particular frequency could be obtained.

Experimental Results

The experimental results are shown in Figs. 4, 5, 6 and 7. In all the graphs the ratio R of the amplitude at any given frequency to the static amplitude (frequency zero) is plotted against frequency. The range of displacement, which is proportional to the orifice area a_o, is inversely proportional to the sensitivity.

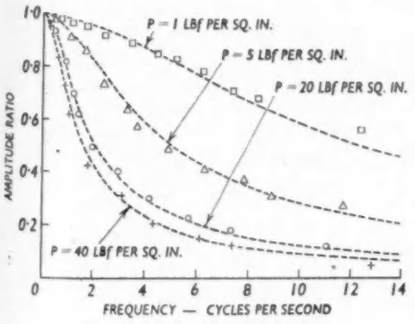

P = 1 LBf PER SQ. IN.
P = 5 LBf PER SQ. IN.
P = 20 LBf PER SQ. IN.
P = 40 LBf PER SQ. IN.
AMPLITUDE RATIO
FREQUENCY — CYCLES PER SECOND
Nozzle diameter = 0·045in
Range of displacement = 0·001in
Volume = 0·92 cubic inches

Fig. 4—Effect of pressure, P

Fig. 4 shows the effect of using different values of the constant operating pressure P for a given range L and circuit volume V. The range is 0·001in (0·025mm), the volume is 0·92 cubic inch (15·1 cubic centimetre) and the nozzle diameter is 0·045in (1·125mm).

The observed values of R are shown as discrete points and *the curves drawn with a broken line are obtained from the theoretical analysis*. These will be discussed later.

Fig. 5 shows the effect of changing the

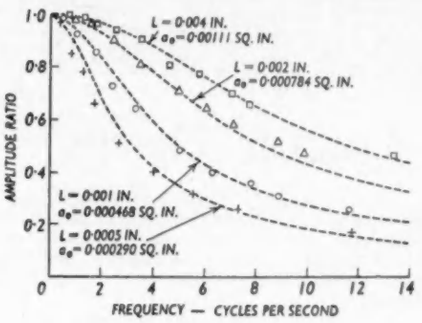

L = 0·004 IN.
a_o = 0·00111 SQ. IN.
L = 0·002 IN.
a_o = 0·000784 SQ. IN.
L = 0·001 IN.
a_o = 0·000468 SQ. IN.
L = 0·0005 IN.
a_o = 0·000290 SQ. IN.
AMPLITUDE RATIO
FREQUENCY — CYCLES PER SECOND
Nozzle diameter = 0·045in
Operating pressure = 5 lbf per square inch
Volume = 0·92 cubic inches

Fig. 5—Effect of range of displacement, L (or orifice area, a_o)

range when the operating pressure is held at 5 lbf per square inch (0·35 kgf per square centimetre). The circuit volume and nozzle diameter are as for Fig. 4.

Fig. 6 shows the effect of changing the

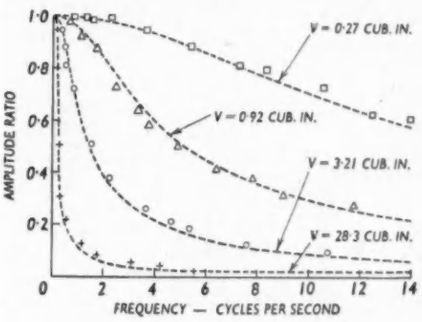

V = 0·27 CUB. IN.
V = 0·92 CUB. IN.
V = 3·21 CUB. IN.
V = 28·3 CUB. IN.
AMPLITUDE RATIO
FREQUENCY — CYCLES PER SECOND
Nozzle diameter = 0·45in
Operating pressure = 5 lbf per square inch
Range of displacement = 0·001in

Fig. 6—Effect of volume, V

circuit volume by changing the bore diameter. The operating pressure is 5 lbf per square inch (0·35 kgf per square centimetre) and the range and nozzle diameter are as for Fig. 4.

If, for a given range, a nozzle of different diameter is used this will require an orifice of correspondingly different size and the mean rate of flow will be changed, so altering the frequency response. Fig. 7 shows the relationship between the amplitude ratio and

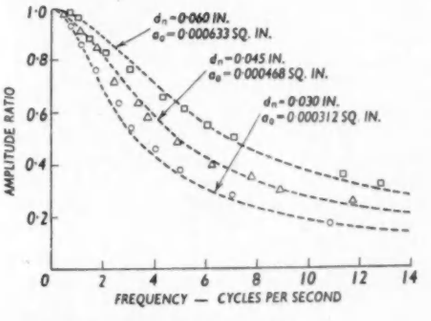

d_n = 0·060 IN.
a_o = 0·000633 SQ. IN.
d_n = 0·045 IN.
a_o = 0·000468 SQ. IN.
d_n = 0·030 IN.
a_o = 0·000312 SQ. IN.
AMPLITUDE RATIO
FREQUENCY — CYCLES PER SECOND
Operating pressure = 5 lbf per square inch
Range of displacement = 0·001in
Volume = 0·92 cubic inches

Fig. 7—Effect of nozzle diameter, d_n

the frequency for three different nozzles. In each case the operating pressure is 5 lbf per square inch (0·35 kgf per square centimetre), the range is 0·001in (0–025mm) and the circuit volume is 0·92 cubic inch (15·1 cubic centimetre).

Comparison of Experimental Results with Theory

In Figs. 4, 5, 6 and 7 the curves drawn with a broken line represent the theoretical relationship between the amplitude ratio and the frequency. They are obtained, for each set of conditions, by using Table II to calculate the appropriate values of K. The expressions for K in terms of the orifice area a_o are used, the values of a_o being determined by measurement on an optical projector. Flow measurements showed that although the value of c_o varied between the several orifices used a value of 0·95 could be assumed to an accuracy of about $\pm 0{\cdot}03$. Assuming a temperature of 20 deg. Cent. in the system k_φ was taken to be $2{\cdot}96 \times 10^{-6}$, calculated in inch units. ($k_\varphi = \rho_o/p_o$ where ρ_o is the density of dry air at pressure p_o and temperature 20 deg. Cent.)

In comparing the theoretical curves with the experimentally observed values, account must be taken of the fact that the experimental results cannot be considered accurate to better than about ± 5 per cent. With regard to the theoretical results an analysis of the factors contributing to uncertainty in the value of K indicates that a most optimistic estimate of the accuracy of this value is $+5$ per cent to -3 per cent. From the expression for the amplitude ratio R in terms of K and the frequency we can deduce that this uncertainty in K leads to a corresponding uncertainty in R given by

$$\text{Percentage error of } R = (1 - R^2) \times \text{percentage error of } K$$

The discrepancies between the theoretical and experimental results seen in Figs. 4, 5, 6 and 7 are largely covered by the combined estimates of uncertainty noted above so that no significant shortcomings of the theory are demonstrated.

Conclusions

The results obtained indicate a marked limitation of the pneumatic technique in applications requiring good dynamic response. Clearly, even under the most advantageous conditions, i.e., low pressure, low sensitivity (large range) and small volume, the measurement of displacements changing at more than a few cycles per second can be subject to substantial error.

Referring to Fig. 6, it is worth noting that the largest circuit volume examined, i.e. 28·3 cubic inch (464 cubic centimetre) is of a magnitude which would rarely occur in practice. The two smallest volumes examined are more truly representative of conditions encountered in a majority of applications.

With regard to Fig. 4, the apparently considerable advantage of a low pressure can often be offset in practice by the characteristics of the particular pressure indicator used. Low pressure indicators, particularly liquid manometers, may have appreciable inertia in relation to the relatively small forces available to work them and thus be slower in operation than high pressure indicators. Thus in the overall result a high pressure system may well compare more favourably with an otherwise similar low pressure system than is immediately inferred from Fig. 4.

The comparison between the experimental and theoretical results shows a measure of

agreement which is, to the authors, somewhat unexpected. The theory employed is so much simplified and so broad in its assumptions that much greater discrepancies would be in no way remarkable. It is clear, however, that this very elementary theory is in fact quite sufficiently accurate to be a most useful aid in design calculations.

ACKNOWLEDGMENTS

The work described above has been carried out as part of the research programme of the National Physical Laboratory and this paper is published by permission of the Director of the Laboratory.

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Developments in Tractor Design

TWO new "Implematic" agricultural tractors, manufactured by David Brown Tractors Ltd., Meltham, Huddersfield, Yorkshire, will be given their first public showing at the Royal Smithfield Show which opens at Earls Court on December 4. The "Implematic" tractor was first introduced in January, 1960 (THE ENGINEER, December 11, 1959) and of all the models so far built, over 80 per cent have been exported to ninety-five countries.

The most powerful tractor in the range is the new "990" model illustrated below, which develops 52 b.h.p. at 2000 r.p.m. It has a newly designed four-cylinder direct-injection diesel engine of 3⅜in bore by 4½in stroke, and a compression ratio of 17 : 1. The stroke to bore ratio of 1·25 is, the manufacturer states, the optimum to give the highest thermal efficiency in a medium-speed diesel engine.

Five-furrow ley ploughing with the "990" "Implematic" tractor

The combined cylinder block and crankcase of "Chromidium" alloy iron is extensively ribbed to give increased rigidity and quiet running. The main bearing caps, of arch design, which are dowelled to the block, are fitted with steel-backed reticular aluminium tin bearing shells in the lower halves and with steel-backed white metal in the upper halves. The crankshaft is a chrome molybdenum steel forging with 2½in diameter main bearings and 2¼in diameter crankpins, carrying on the front end a 1⅜in diameter splined extension capable of transmitting full engine power for auxiliary drives. The connecting rods are fitted with steel-backed recticular aluminium tin big end bearings and high density phosphor bronze little end bushes.

The cylinder head incorporates the integral thermostat housing, integral valve guides and cooling water distribution system, and cross flow porting with separate inlet ports for each cylinder on one side of the head and separate exhaust ports on the other. This system is claimed by the manufacturer to give the highest possible volumetric efficiency consistent with optimum swirl rate in the cylinders and to ensure clean combustion, as well as keeping heat away from the induction side of the engine so that the fullest possible charge of cool air is delivered to the cylinder.

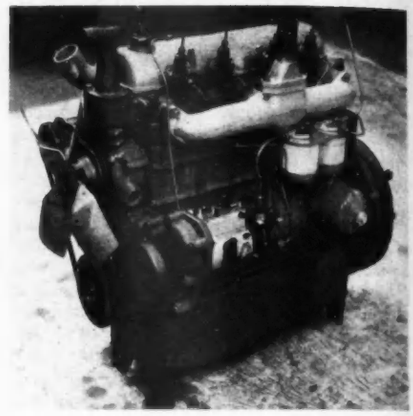
The injectors, as in previous David Brown engines, are mounted in integral pockets in the cylinder head outside the valve gear cover. The inlet manifold incorporates an ether device for starting under very cold conditions. Mounted on the front of the cylinder block and pressure lubricated from the engine system, the timing gear chain comprises only four fine pitch spur gears. Provision is made in the timing gear backplate to mount the gear-driven power steering pump. The lubricating oil pump is of the gear pattern with 2½ g.p.m. capacity at 1600 r.p.m. Injection equipment is of C.A.V. manufacture and consists of a distributor injection pump, with an all-speed mechanical governor, fed by a mechanically operated feed pump on the side of the cylinder block. The air cleaner on the "990" has been sited in front of the radiator.

The British Standard power take-off speed of 540 r.p.m. is provided in two combinations; in low ratio at the rated engine speed of 1800 r.p.m., 43 h.p. is available, and in high ratio at 1100 r.p.m. engine speed, 28 h.p. is available at the power take-off. The American standard of 1000 r.p.m. power take-off speed is met in high ratio with the engine running at 2000 r.p.m., giving 46 h.p. at the power take-off.

A new front axle has been introduced on the "990" giving a ground clearance of 20in, and in order to maintain the clearance, the height of rear lift has been increased so that mounted implements can be raised to axle level. A new semi-automatic latch embodied in the hydraulic system can be used to lock the implement in the raised position for transport. Category I and II linkage is fitted as standard together with a universal swinging drawbar.

The "990" is available either with a single-stage clutch, or with a two-stage clutch providing "live" hydraulics and "live" power take-off.

In the range of medium power tractors David Brown now have two models, an improved version of the "950" (THE ENGINEER, January 30 and December 11, 1959) and the "880," both of which are powered by the same 42·5 b.h.p. engine. The new "880" is geared for faster travel by virtue of higher ratios throughout the six-speed range, the maximum full-power speed of 16·3 m.p.h. being more than 3 m.p.h. faster than the "950." This tractor has also been equipped with the new front axle and because of its larger tyres, ground clearance is increased to 19½in, thus making it eminently suitable for row-crop work. The power take-off shaft has a two-speed range.



The new three-litre, 52 b.h.p., four-cylinder direct-injection diesel engine which is fitted in the new David Brown "990" "Implematic" tractor. A "slave" sump is fitted to the engine illustrated here

The model "850" tractor (THE ENGINEER, February 19, 1960) has been improved upon. The construction of its front axle is substantially as previously, but ground clearance has been increased to 18½in by lengthening the vertical stub axle spindles. The tractor is available with livedrive power take-off or non-livedrive, but, as on the "880," there is now included a two-speed range on the power take-off shaft. Because it is thought by David Brown that the use of the belt pulley is diminishing, the belt pulley unit is now supplied to bolt on to the back of the power take-off case instead of being an integral part of it. As on the "990" already described, the height of the rear lift has been increased in order to maintain ground clearance, and the semi-automatic latch has been incorporated to lock implements in the raised position for transport.

Narrow versions of both the "850" and "880" are available, their overall width being only 48in.

The international Unified thread system has been incorporated in the new tractors and the change has been made on all new components. Tractors having existing engines still retain the British Standard Fine thread on the engine, but on all other parts the change has been made to Unified Coarse thread. To avoid confusion all castings which are tapped Unified threads have a letter "U" cast on them.

EXTENDED BUSES.—The first of twenty "Routemaster" vehicles extended in length from 27ft 7in to 29ft 11in has now commenced operation with London Transport. These vehicles, designated RML, were modified from standard vehicles in a late stage of construction and are recognisable by having one small window in each saloon at each side: four more seats are fitted, bringing the seating capacity up from sixty-four to seventy-two. Since the new bay is at the rear end of the gearbox (see page 415, September 24, 1954) an extension shaft is added to keep the front end of the final propeller shaft in the section of the rear radius arm anchorages. The front wheels have 10·00×20 fourteen-ply tyres instead of 9·00×20 fourteen-ply. The unladen weight is 7 tons 12 cwt, corresponding to 235 lb per seated passenger, compared to 253 lb for the RM.

Letters to the Editor

AN OUTSPOKEN PRESIDENT

SIR,—Your leading article in the current issue has encouraged me to speak out too. It led me to wonder what would have been the reflections of Telford, the first President of the Civils, of Robert Stephenson who succeeded to the Chair in his day, or of its distinguished member I. K. Brunel, on reading it. Their names were household words, yet how many men in the street could mention the names of three distinguished engineers of our day ? Why is this ?

One obvious reason is the growth of group effort as compared with that of individuals and another is the growth of specialisation, but are they sufficient in themselves to account for the change ? I think not. Brunel, for one, set out the position of the engineer in a letter in reply to an invitation on behalf of the Government of the King of Sardinia to undertake the direction of the works of a proposed railway from Genoa to Alessandria. I quote.* " In the first place I assume that if the direction of the works be confided in me as the engineer, the same degree of confidence will be placed in me, and the same authority will result from that confidence, as would be the case in England—that is to say, I should be the confidential adviser of the Government in all engineering questions connected with the railway, my communications would in all matters be made direct with the Government, and as long as I continued to be responsible for the direction of the works no other engineer would be consulted or allowed to interfere. Of course I claim no right to direct anything but that which has the sanction of the Government ; but I should claim to be their sole adviser on all engineering points (connected with the construction of the railway), and to possess their entire confidence ; and also that, if any portion of that full confidence were at any time withdrawn, the fact should be immediately communicated to me ; when, after making every possible arrangement to prevent inconvenience to the Government, I might withdraw from the direction of the work. *This is the position which an engineer of any standing occupies in this country, whether acting for the Government or for individuals*" (my italics) " and I believe it to be as fully essential for the success of the proposed undertaking, and as necessary for the interests of His Majesty's Government as for my own satisfaction, that I should be placed in a similar position."

In the light of this, can one imagine that he, or any of his contemporaries, had any one of them been The Engineer of British Railways (no prefix or suffix) agreeing to remain in that position while a lay Government, advised by an outside lay committee, held up his work while discussing such a purely engineering subject as the relative advantages of diesel and electric traction for the Euston–Crewe line ?

In these days, when one sits round a table considering an engineering project, the client, the various specialised contractors, possibly a Government Department or two, and the Consulting Engineer (if any) are all there, they all express their opinions and the speed and efficiency of execution are, so to speak, the lowest common multiple. Could Stephenson have built the London and Birmingham, or Brunel the Great Western in the time they did, using muscle power and explosives alone, under such conditions ? They met their contractors on site, saw that they did the job or replaced them, certified their accounts which were paid by the Company without question, and decided how much the Company should incur in the way of civil engineering work. The result was two main lines whose easy gradients have been earning dividends for a century and a quarter.

Incidentally, they neither needed, nor would have tolerated admonition from outside bodies to make their works aesthetically acceptable. The two Menai bridges, the Royal Border bridge, and Maidenhead bridge are examples where the engineer designed unaided, and the Company paid for, structures which have satisfied succeeding generations in fitness for their surroundings.

Until engineers in positions of authority insist that all matters which are directly dependent upon engineering considerations shall be left in their hands by the business community and by Government, succeeding occupants of the Presidential Chairs once held by these men will continue to lament that the true functions of the engineer are not understood in their day.

J. R. HARDING

Sutton Coldfield,
Warwicks.
November 18, 1961.

* *The Life of Isambard Kingdom Brunel*, by Isambard Brunel, page 475.

HIGH-DEFINITION TELEVISION ON V.H.F.

SIR,—In your issue of November 10 you discuss the booklet recently issued by the Independent Television Authority describing a plan for changing the television standard from 405 to 625 lines. You say that it seemed unfortunate that the arguments in this booklet were not acted upon in time for Britain to have sought assignments in a re-channelled v.h.f. spectrum at the Stockholm Broadcasting Conference earlier this year.

In my opinion the I.T.A.'s plan has disadvantages which would seem to make it unacceptable. Perhaps you made your comment without a knowledge of other methods of changeover at present under discussion. All these methods have disadvantages of one kind or another and, if the Government decides that the line standard should be changed, much more thought will have to be given to the best method of achieving it.

HAROLD BISHOP,
Director of Engineering.

Broadcasting House,
London,
November 14, 1961.

NOTEWORTHY LOCOMOTIVES OF 1911

SIR,—There are a number of points in Mr. Poultney's article in your issue of November 10 which, I feel, call for comment.

First, the reference to the " considerable notoriety " achieved by J. G. Robinson's 2–8–0 locomotives is a little unfortunate. These locomotives were generally considered to be very satisfactory.

It is hardly correct to suggest that the Great Western 43XX class 2–6–0's were the first mixed-traffic locomotives in this country. Mixed-traffic locomotives were introduced many years earlier by a number of companies, notably the Great Northern and the London and South Western. The " Special DX " 0–6–0's on the London and North Western, while not designated mixed-traffic engines, were nevertheless employed on a very wide range of duties. The Bowen-Cooke 0–8–2T class should be included in the notable locomotives of 1911. This design may have been inspired by the Hughes 0–8–2T class, but it was the first specifically for banking and hump shunting duties on the L.N.W.R. The superheaters fitted to the North Eastern Z.1 class " Atlantics " had twenty-four elements, not sets of elements. The tenders were not of enlarged design ; the water and coal capacity were the same as in the tenders coupled to the R.1 class 4–4–0's and S. class 4–6–0's built in 1908 ; the slight increase in weight was almost entirely due to the fitting of a brake reservoir beneath the back of the tender. The 2–6–0 wheel arrangement was used on the Midland and South Western Junction Railway in addition to the other railways mentioned by Mr. Poultney.

The most reliable published dimensions of Lancashire and Yorkshire locomotives show the heating surface of the Hughes superheated 2–4–2T's of 1911 to be :

Tubes, square feet	706·8
Firebox, square feet	111·8
Evaporative, square feet	818·6
Superheater, square feet	171·2
Combined, square feet	989·8

In referring to these engines as the largest of their kind it should be appreciated that they weighed only a few hundredweight more than the G.W. 36XX class and had smaller boilers and fireboxes than the Swindon engines. Contemporary descriptions of the Robinson 2–8–0's give adhesive and total engine weights of 65 tons and 72 tons in working order, and those of the East Indian 2–8–0's as 58 tons and 64·25 tons. There may well have been a discrepancy between the published and actual weights, however. The adhesive weight of the L.B. and S.C. H2 class " Atlantic " was stated at the time of building to be 37·5 tons and the total engine weight 68·5 tons, both in working order.

J. D. GOFFEY

West Worthing,
November 15, 1961.

Books Received

Industrial Furnaces. Vol. 1. Fifth Edition. By W. Trinks and M. H. Mawhinney. John Wiley and Sons, Inc. Price 136s.

Die Grundgesetze der Wörmeübertragung. Grober/Erk. Edited by Dr.-Ing Ulrich Grigull. Springer Verlag, 1961. Price DM 37.50.

Books just published

The Organisation from Within, a Comparative Study of Social Institutions Based on a Socio-therapeutic Approach

178 *pages.*

Publisher : Tavistock Publications (1959) *Ltd.*

by CYRIL SOFER.

Price 25*s.*

The author is a social scientist working at the Tavistock Institute of Human Relations and his book consists of three case studies of a new form of social work consisting of working with organizations towards the achievement of their aims and purposes by a fuller use of the human resources available. A narrative account of the three cases is given, then the author discusses some of the main issues of social consultancy involved in this work.

[Reply Card No. 1281]

History of Broadcasting in the United Kingdom Vol. 1. The Birth of Broadcasting

425 *pages. Illustrations.*

Publisher : Oxford University Press.

by ASA BRIGGS

Price 42*s.*

This is the first part of a projected three- or four-volume history of broadcasting in the United Kingdom. It is written as a business and social history and is not concerned with technical developments, although it contains much information about the early experiments. This first volume covers early amateur experiments in wireless telephony, pioneer days in England, and the first four years of the B.B.C.'s existence as a private company before it became a public corporation in January 1927.

[Reply Card No. 1322]

Progress in Non-destructive Testing. Volume 3

225 *pages. Illustrations. Diagrams.*

Publisher : Heywood and Co. Ltd.

Edited by E. G. STANFORD, M.Sc., Ph.D., A.M.I.E.E., F.Inst.P., and J. H. FEARON, B.Sc., A.M.I.E.E.

Price 55*s.*

This is the third of an annual series of international volumes containing critical reviews of special aspects of the general subject. The current volume contains articles on optical methods, xeroradiography, X-ray spectrochemical analysis, the dynamic mechanical properties and structures of polymers, hysteresis methods, coupled circuit theory for electromagnetic testing, and X-ray microscopy. There is no index.

[Reply Card No. 1332]

Two Hundred and Fifty Years of Shipbuilding

279 *pages. Illustrations. Diagrams.*

Publisher : Scott's Shipbuilding and Engineering Company Ltd., Greenock.

No price given.

This is the fourth edition of the book first published in 1906 under the title *Two Centuries of Shipbuilding*. The contents have been revised and brought up-to-date both technically and historically since the third edition in 1950. The length of the book is the same, but there are many new illustrations and data, principally about the restored head offices, ships built since 1950, and the re-organised shipyard and engineering departments.

[Reply Card No. 1333]

Scottish Railways

230 *pages. Illustrations.*

Publisher : Thomas Nelson and Sons Ltd.

by O. S. NOCK, B.Sc., M.I.C.E., M.I.Mech.E., M.I.Loco.E.

Price 25*s.*

This is a revised edition of a book originally published in 1950. Amendments to chapters dealing with modern equipment have been included, the appendices on Scottish locomotive performances have been brought up to date, and a new chapter on modern express freight services has been added. The plates are substantially the same.

[Reply Card No. 1334]

Engineering Materials Science

546 *pages. Diagrams.*

Publisher : Chapman and Hall Ltd.

by CEDRIC W. RICHARDS.

Price 60*s.*

Aimed at preparing the student of engineering in the use of the materials at his disposal, this book gives a fundamental account of their make-up, and the underlying theories which account for their behaviour. It is useful for the reader to have some knowledge of stresses and strains. The book is divided into three parts. Part 1 deals with general principles, and is devoted mainly to structure of solid materials. Part 2 deals with mechanical behaviour, and is split into sections on static tension, static compression, static bending, complex static stresses, dynamic and thermal effects, creep, fatigue, and hardness. Part 3 deals with physical behaviour, and contains chapters on electrical and magnetic properties, thermal properties, corrosion, and radiation. Also included are an appendix of typical properties of metals, organic materials, and ceramics at room temperature ; answers to set problems ; and an index.

[Reply Card No. 1335]

Guide to Design Criteria for Metal Compression Members

93 *pages. Diagrams.*

Publisher : Crosby Lockwood and Son Ltd. 1961

The Column Research Council 1960.

Price 42*s.*

The Column Research Council was formed in the U.S.A. in 1944 and in co-operation with Dr. F. Bleich in his *Buckling Strength of Metal Structures* (1952) surveyed the development of the subject of metal compression members up to that date. The present publication covers work which has been done since and includes chapters on centrally loaded columns, compression member details, laterally unsupported beams and beam columns. There is a list of references to each chapter and a name and subject index.

[Reply Card No. 1338]

Verbundtrager Berechnungsverfahren fur die Bruckenbaupraxis

149 *pages. Diagrams.*

Publisher : Springer-Verlag, Heidelberger Platz 3, *Berlin-Wilmersdorf.*

by BERNHARD FRITZ

Price DM. 31.50

During the last decade the number of publications dealing with calculation and proposed designs of compound bridge girders has grown to such an extent that a monograph was deemed likely to be of considerable assistance to those wishing to familiarise themselves with the subject. The author in addition outlines a general method for continuous spans with variable sections which takes into account the creep and shrinkage of the concrete.

[Reply Card No. 1340]

Betrieb von Elektrizitatswerken

490 *pages. Diagrams.*

Publisher : Springer-Verlag, Heidelberger Platz 3, *Berlin-Wilmersdorf.*

by HEINRICH FREIBERGER

Price DM. 57

One of the outstanding phenomena of the present technological age is the development of electricity in its interaction with other factors of social transition. The present author who, over many years, has played a leading part in the German electricity supply industry, discusses in an encyclopaedic manner the rise and present state of the industry, related development elsewhere being considered *passim*. Among the aspects which are summarised are legal and political traditions, organisation and management, distribution and consumer relations, planning and operation of plant, financial policy and legal problems, oil *versus* coal, nuclear energy, and the influence of public authorities.

[Reply Card No. 1341]

Uber das Kuhlen von Beton

146 pages. *Diagrams.*

Publisher : Springer-Verlag, Heidelberger Platz 3, *Berlin-Wilmersdorf.*

by WOLFGANG MANDRY

Price DM. 28.50

While the heating of concrete, due to the hydration of cement, does not matter with thin structures, it is a serious problem in thick dams, as may be gathered from the fact that in a dam like the Mauvoisin the heat evolved is equivalent to that contained in 5000 tonnes of coal, while a temperature rise of 10 deg. Cent. in a mass of 1,000,000 cubic metres causes a shrinkage of 300 cubic metres. The present book deals with the heating of cement and the stresses caused by subsequent cooling, and goes on to describe the measures adopted to prevent the build-up of dangerous stress—pre-cooling of concrete, and the cooling of the completed structure by means of a system of refrigerated pipes.

[Reply Card No. 1342]

Grosskessel-Feuerungen Theorie, Bau und Regelung

362 *pages. Diagrams.*

Publisher : Springer-Verlag, Heidelberger Platz 3, *Berlin-Wilmersdorf.*

by RICHARD DOLEZAL

Price DM. 69

Large steam-generating plant involves a variety of special problems which cannot be solved by simply scaling up larger units. In addition to difficulties arising from the trend towards larger and larger boilers, there is a multiplicity of factors involved about whose relative significance there remain many differences of opinion, as reflected in the variety of designs which have been carried out and projected. The book deals with the theory, construction, and operation of boilers of over 125 tonnes per hour up to the largest sizes at present under construction with steam capacities of 1700 tonnes per hour.

[Reply Card No. 1343]

Radio for Examinations

364 *pages. Diagrams.*

Publisher : Cleaver-Hume Press Ltd.

by H. I. F. PEEL, M.Sc.Tech., A.M.I.E.E.

Price 55*s.*

This book is intended to help students with the syllabuses in advanced radio engineering, and a sound basic knowledge of the subject is therefore assumed. Special attention has been given to mathematical analysis of circuits, and there are worked examples at each major stage. Chapters are on properties of tuned and coupled circuits, valve amplifiers, oscillators, amplitude modulation, transmission lines, propagation of radio waves, aerials and aerial array, direction finding and navigational aids, radio receivers, cathode ray oscillograph, television and facsimile, above 30 mc/s, microphones and loudspeakers, filters and attenuators, frequency modulation, radio-telephone systems, and transistors. There are also appendices on decibels, nepers, network theorems, photo-electric cells, bandwidth required by f.m. transmission, common results, essential formulae, and useful constants and equivalents. Lists of references, examination questions with answers, and an index are also included.

[Reply Card No. 1352]

SHORTER REPORTS

Faraday Lecture, 1961/62

THE first I.E.E. Faraday Lecture of the current series was given at the Colston Hall, Bristol, on November 21. The lecture, on "Expanding Horizons in Communications," was given by Mr. D. A. Barron, deputy engineer-in-chief of the British Post Office. Between now and March 29, 1962, the lecture is being delivered at eleven other centres and will be in London, at the Central Hall, Westminster, on February 14, 1962. In this lecture the means available for automatically connecting two subscribers are reviewed, with demonstrations of the principles of local, national (s.t.d.) and international automatic switching. The ways in which a local telephone connection can be built up progressively into a world-wide system controlled entirely by the subscribers are explained. The lecture continues to discuss cables and their characteristics, and the development of multi-channel radio links for internal communications. It is shown how demand still exceeds the capacity of such inter-city systems, and the possibilities of transmission by waveguide are described. Dealing with intercontinental communications, the extending use of undersea cables to replace low-capacity radio links of variable performance is reviewed, and a demonstration is given of how T.A.S.I. (time assignment speech interpolation) approximately doubles the capacity of a given cable. In conclusion the lecture reviews the approach of satellite communications and their significance in terms of traffic capacity and the practicability of transoceanic television. In addition to the T.A.S.I. demonstration, other aspects of the subject illustrated by experiments, models and animated diagrams include automatic dialling, music transmission by waveguide, and the tracking of communications satellites by means of swinging ground aerials.

Instrument Conference in Holland

THE Society of Instrument Technology, 20, Queen Anne Street, London, W.1, and the Royal Dutch Institute of Engineers are organising a joint conference to be held on April 10 to 13, 1962, in Amsterdam. The programme is being arranged to encourage discussion and exchange of information on the present state and future trends of measurement and control technology in Britain and Holland. Six technical papers will be presented and discussed, covering new measurement methods such as direct reading spectrography, X-ray fluorescence chromatography, and optical measuring techniques; descriptions of working automation projects in the biscuit industry and mine shaft sinking; and control in manufacturing industry. Visits will include: the Royal Dutch Steelworks at Ijmuiden; Delft University; Royal Dutch Shell Laboratory and the National Aircraft Laboratory at Amsterdam; and the Philips Works Technical University at Eindhoven. It may be possible to entertain a few applications from non-S.I.T. members, who are asked to contact the organising secretary, Mr. I. V. Idelson, Mullard Equipment Ltd., Manor Royal, Crawley, Sussex, as soon as possible.

National College of Heating, Ventilating, Refrigeration and Fan Engineering

BEFORE the establishment of the National College in 1948 and its opening to students in September of that year there had been little provision for advanced study and research in heating, ventilating, air conditioning or refrigeration. As a result of an enquiry in 1942, a specialist full-time course was provided in 1944, and later the Percy Report gave the industry the opportunity to apply for a National College to which the Minister of Education acceded. The first premises were an annexe to the Borough Polytechnic, and a laboratory was completed in the grounds in 1950. Four years later plans were prepared to provide additional accommodation but abandoned in favour of a new building on a site in Southwark Bridge Road, London, S.E.1.

The plans provided for a five-storey building which incorporates well-equipped laboratories for work on problems concerned with heating, ventilating, air conditioning, fan engineering, refrigeration and heat transfer and also for research projects. The mechanical services installed serve the dual purpose of utility and instruction, and include a selection of heating, ventilating, and air-conditioning systems. A number of heat generating appliances are in the heating plant laboratory and the fan laboratory includes an "anechoic" chamber. There are physics, air-conditioning and research laboratories, lecture rooms, and a lecture theatre which has been provided by G. N. Haden and Sons, and has been named the Nelson Haden Lecture Theatre.

The National College was completed earlier this year, and was officially opened on September 20, by Sir David Eccles the Minister of Education. In introducing Sir David, Mr. H. A. Secretan, the chairman of the board of governors, reviewed the developments leading up to the construction of the College, and mentioned that the industries concerned had contributed over £65,000 in cash and equipment in response to an appeal to meet the Government challenge that industry should play its part in the provision of a National College. Now the college is established the chairman appealed for further help to provide the necessary hostel accommodation for students who, in addition to technical training, needed training in human relationships which only the corporate life of a residential college can provide. In declaring the college open, the Minister mentioned that the annual turnover of the industry was about £75,000,000 per annum, and went on to give figures relating to sections of the industry, all of which were indicative of its prosperity and of the expansion taking place. Sir David warned the industry about being complacent, and mentioned the need to support the means for training designers, suggesting that individual firms might sponsor professorships.

Staines By-Pass

THE Staines By-pass on the A.30 (London–Penzance) trunk road was opened by Mr. John Hay, M.P., Parliamentary Secretary to the Ministry of Transport, last Friday. The by-pass is 2 miles in length; it crosses the Thames by the new Runnymede bridge. The cost of its construction has been over £2,000,000.

The new road leaves the A.30 at the Billet Bridge roundabout, on the north-eastern outskirts of Staines and runs north of the town to join Wraysbury Road at a new roundabout. It then turns southward to cross the river on the new Runnymede Bridge, rejoining the A.30 at Egham, where the existing roundabout has been enlarged. It has dual 24ft carriageways. These have a design capacity of 2500 passenger car units an hour, and will cater for all foreseeable traffic, the Ministry of Transport states, since, in the long term, this part of A.30 will be replaced for through traffic by the Basingstoke motorway. The section of the road between the roundabouts at Wraysbury Road and Egham, including the bridge, has, however, been designed for eventual widening to dual 36ft carriageways. This is because this section will eventually form part of the North Orbital Road. For the same reason the roundabouts have been so designed as to enable flyovers to be provided at the junctions as and when they are needed.

The road has been constructed on embankments, 20ft high in places. About 500,000 cubic yards of filling material had to be imported for the embankments, and some strengthening and improvement of local roads was necessary to carry this material from its source. On the section from Billet Bridge to the Runnymede Bridge, the contractor encountered unexpected difficulties in constructing the embankment. At one point, a large area of peat and other unsuitable material had to be excavated and replaced by ballast. At one time, it seemed that this might delay the work, but the lost time has been made up.

The Runnymede Bridge carries the by-pass over the Thames at Bell Weir. It was originally designed by the late Sir Edwin Lutyens, working in collaboration with the late Mr. H. FitzSimons, consulting engineer. Since then, however, the engineering structure of the bridge has been completely re-designed by Messrs. C. W. Glover and Partners. The architectural treatment of Sir Edwin Lutyens' design was retained. The consulting architect was Mr. George Stewart, F.R.I.B.A., who worked on the original design. These facts are likely to be familiar already to readers of THE ENGINEER, since the design and cost of the bridge became the subject of a somewhat sharp controversy at the time that the tenders for the bridge were being considered. The matter was reported in our issue of October 23, 1959, page 483, and commented upon in a leading article the following week; an independent report on the rejected design was summarised in our issue of November 6, and on November 13 we published a correspondent's views and a statement by the Minister.

The bridge, as now completed, has a single arch span of 173ft over the river and one small arch span of 31ft in each shore section. It is of composite construction, incorporating light welded steel arches embedded in concrete, and the main arch is two-pinned. The width of the bridge between parapets is 100ft. The foundations are described as "of the cellular direct bearing type" and are carried down into the London Blue Clay. The sides of the bridge and side arch soffits are faced with 2in Old English red hand-made bricks. The soffit and face of the main arch are constructed in white concrete, and the parapet is of white Portland stone.

In addition to the main structure, a considerable widening of the river on the Wraysbury side has been done, and river protection works with stepped embankments have been formed on both banks. A prestressed concrete bridge carrying the towpath on the Egham bank over the new flood relief channel has also been built. The Ministry states that "the contractor was aware of the possibility of flood conditions during construction of the bridge, but those proved worse than expected. Wet weather in the autumn of 1960 added to the difficulties and there was very severe flooding. At one time, divers were used for work below water level in the flooded river."

In the Surrey section of the by-pass south of the Thames the approach road is carried on an embankment the height of which varies between 8ft and 17ft. Owing to the presence of a layer of compressible silt, the embankment had to be constructed as far as possible in advance of the roadworks to allow for settlement. A flood relief bridge has been constructed through the embankment and, on the eastern side, a flood relief channel with an outlet to the river.

The roadworks north of Runnymede Bridge, including a small section in Buckinghamshire, were under the direction of Mr. H. S. Andrew, M.I.C.E., M.I.Mun.E., Middlesex County Engineer and Surveyor. The works south of the bridge were directed by Mr. D. S. Samuel, M.I.C.E., M.I.Mun.E., Surrey County Surveyor. The main contractor for the road between Billet and Runnymede bridges was Richard Costain Ltd. The contractor for Runnymede bridge was W. and C. French Ltd. and the contractor for the section of the roadworks in Surrey was Wilson Lovatt and Sons Ltd.

SHORTER REPORTS *(Continued)*

Gas-Turbine-Driven Plant

WHILE air at relatively low pressures can conveniently be obtained by bleeding from a gas turbine, supplies at higher pressures demand a positive displacement compressor which, for reasons of capital and running cost, is normally coupled to a low-speed power unit. For standby emergency plant, however, the quick starting and from cold and low weight of a gas turbine may justify its use with a positive displacement compressor, and the installed cost of the plant, using a quantity-production engine such as the Standard IS/250, may be no greater or even less, particularly if the size of the positive displacement compressor can be reduced by supplying it with air bled from the engine compressor. In certain applications, however, this integration of engine and load may not be attractive ; for instance, the gas turbine can save in fuel if, at least on part load, it aspires coal mine upcast gas or the dilute natural gas that is available on oil fields, while it may well be that the compressor is required to deliver not air but, for instance, nitrogen used for purging tanks holding inflammable fluids.

For these special applications, Auto Diesels Ltd., Braby House, Smithfield Street, London, E.C.1, is supplying the IS/250 gas turbine that it manufactures under licence from The Standard Motor Company Ltd. to power a 630 cubic foot per minute F.A.D. 100 lb per square inch " Broomwade " compressor. The compressor, which has two sliding-vane rotors in series, runs up to 1650 r.p.m. ; it is lubricated, sealed, and cooled by oil injected at the air intakes of each stage, the oil settling in the air receiver and passing through the large, pressurised cooler seen in our illustration to a metering pump and back to the injectors.

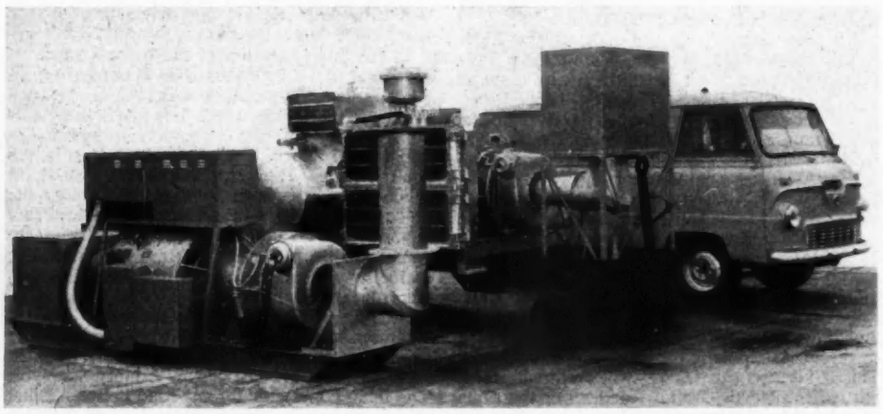
The engine is connected to the compressor by a centrifugal clutch which commences to engage at 1150 r.p.m. Both because of this clutch and because the efficiency of a gas turbine is so bad at reduced speeds, the output of the set is regulated by turbine speed only down to 1375 compressor r.p.m. ; if at this speed the delivery is excessive, a valve between the air cleaner and the compressor is closed by an air-operated valve. In this application the engine speed is increased over that for, say, generating, 1650 r.p.m. corresponding to 26,400 r.p.m. instead of the normal 24,000.

Apart from adaptations to meet this particular application, the engine is very much as described on page 406, March 15, 1957, but the rated output has dropped to 220 b.h.p. at a turbine inlet temperature of 800 deg. Cent. One difference is that, instead of the turbine being in a single piece, the straight portion of the blades is machined from a forging and the inner, curved part (the " exducer ") is made separately.

This engine is also available as an air compressor of the engine-bleed design, a number having been sold for use as aero-engine starters (see page 409, September 2, 1960). Our illustration also shows one of these equipments mounted in a Ford van, but whereas the previous illustrations showed a left-hand-drive vehicle manufactured in Cologne, this one is a Dagenham product.

The shaft turbine is incorporated in a 175kVA transportable generating plant that is seen in the illustration ; this also has a centrifugal clutch, starting being by means of 24V batteries. On load, the 240V/415V three-phase output is inherently regulated within $+2\frac{1}{2}$ per cent by the direct-coupled " Magnicon " exciter.

[Reply Card No. 1415]



Three equipments incorporating the 220 h.p. simple gas turbine : in the nearest it is coupled to a 175kVA, 1500 r.p.m. generator and has an open exhaust ; the next is a trolley-mounted 630 c.f.m. vaned-rotor internally-oil-cooled compressor ; and the furthest is an air-bleed compressor for turbine engine starting mounted in a petrol-engined Thames van

Roseires Dam, Sudan

THE main work is due to be formally inaugurated tomorrow on one of the most ambitious projects which British consulting engineers have carried forward in the Sudan—the Roseires dam on the Blue Nile. In 1952 Sir Alexander Gibb and Partners investigated the possibility of a storage dam on the river and recommended the siting and type of construction of the dam. Later the French firm of André Coyne and Jean Bellier were engaged as co-consultants on the project, which is under the direction of Sudan's Ministry of Irrigation and Hydro-Electric Power.

Ultimately the dam will make it possible to store 6,000,000 acre-feet of water. The first stage, which is expected to be completed in the summer of 1967, involves constructing the dam to a height of 200ft above the foundations in the deepest part of the river-bed, at which height it will impound 2,400,000 acre-feet. In the second stage the crest will be raised a further 10m to achieve the full storage capacity.

The dam will be a heavy concrete buttress structure about 3610ft long, flanked on either side by earth embankments about 7 miles long on the west bank and $2\frac{1}{2}$ miles on the east. The concrete section will incorporate five deep sluice gates, each a radial gate, 33ft high by 20ft wide, placed low so as to reduce the accumulation of silt in the reservoir on the upstream side. To the west of the deep sluice section there will be a surface spillway controlled by seven radial gates, each 39ft high by 33ft wide. The combined discharge capacity of all the gates will be about 613,000 cusecs. This compares with the estimated highest discharge, of 381,000 cusecs, in the Blue Nile at Roseires since records began in 1912.

A small service power station of 2MW capacity will be incorporated in the dam to work the gates and other machinery. Provision has been made for a future hydro-electric station equipped with seven 25MW sets. The buttresses in this section have been designed in a way that will allow the power station to be built later without interfering with the operation of the dam.

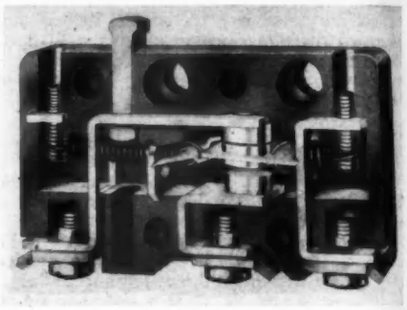
Some 1,100,000 cubic yards of concrete will be used in the dam's structure, together with 4500 tons of steel reinforcement. The foundations will involve 2,800,000 cubic yards of excavation, and 5,300,000 cubic yards of earth will be needed for the embankment dams. The Italian firm of Impresit-Girola-Lodigiani, who were the lowest tenderers, secured the civil engineering contract for a total sum of nearly £20,200,000.

When the first stage of the dam has been completed, water will be provided for the Managil irrigation scheme on a permanent basis without restriction. It will be possible to change and diversify the crop-rotation in the Gezira and Managil areas, providing an additional cotton crop of some 300,000 acres, and to irrigate a further 200,000 acres by gravity on the fringes of the two schemes. These and other benefits will provide a living for some 60,000 new tenant families.

Double-Action Micro-Switch

A DOUBLE-ACTION micro-switch of new design has been developed and marketed by Chilton Electric Products Ltd., Hungerford, Berks. It is available with a variety of accessories and enclosures for a wide field of application as a limit, control and safety switch.

It has been designed and developed to ensure rapid separation of the contacts. As can be seen from the accompanying illustration of the mechanism, when the operating plunger (on the left) is depressed it starts the first snap action of the actuating fork which moves rapidly, knocking the contact carrier and causing it to snap over to the opposite contact. The actual contact pressure is generated by a second spring (on the right) pulling up or down on the contact carrier. Pressure is thus maintained at a constant value which is independent of the position of the operating plunger. Contact pressure is further reinforced by the pressure of the actuating fork and its spring, which makes the switch less sensitive to shock and vibration. It will be seen that, in this mechanism, any unstable condition is limited to the actuating fork and cannot be transmitted from it to the contacts.



Double-action micro-switch

This construction eliminates instability of the kind that can arise in certain micro-switches which use a biased spring to provide the forces for both contact movement and contact pressure. In some of these designs the contact pressure is reduced to zero just before the contacts change their position. In this unstable condition (which can arise at slow operating speeds of the plunger) contact bounce can occur, resulting in excessive burning and overheating of the contacts.

By avoiding this possibility the new Chilton switch enables a very slow or " creep " actuating movement to be transformed into a definite " snap-action " switching operation.

[Reply Card No. 1408]

Circular Brickwork Enclosure for Suppressing Transformer Noise

THE efficacy of a cylindrical brick-built enclosure as a means of suppressing transformer noise is being investigated by Transformers (Watford) Ltd., as was shown by an interesting demonstration last week at the company's works at Sandown Road, Watford, Herts. Like other manufacturers this company is, of course, interested in studying ways of eliminating transformer noise at its source—the stampings that make up the laminated core. But the obvious remedy, that of reducing the working flux density, means an increase in core size, which is uneconomic in the highly competitive field of transformer manufacture. At present it appears to be more economic to concentrate on devising enclosures that will attenuate transformer noise to a tolerable level.

Hitherto most of the effort has been devoted to rectangular enclosures, following the plan form of the transformer. However the advantages of a cylindrical enclosure appealed to Transformers (Watford) Ltd. It was realised that an inherently strong enclosure of circular plan form could be built of only single-brick thickness without the need for any supporting buttresses. The cost would be much less than that of a rectangular enclosure which would necessarily be of double-brick thickness. In addition it was thought that a circular form might show a definite improvement in sound attenuation, compared with a rectangular structure.

To test this theory a cylindrical experimental test cell was designed and built in a yard adjoining the company's works. The structure was built of standard curved bricks obtained from the firm's parent organisation, The London Brick Company Ltd. These bricks are available in various finishes. To accommodate transformers up to 500kVA the test cell, on a concrete plinth, was made 9ft diameter by 8ft high.

For one of the tests a 300kVA distribution transformer having a noise level much higher than average was installed in the enclosure. The noise was raised to an artificially high level by operating the transformer at a flux density 15 per cent above the design value. The noise level was then measured in eight directions at 45 deg. spacing around the enclosure, at distances of 1ft and 6ft from the enclosure and at varying heights. Further measurements were also made in several directions at distances up to 40ft from the enclosure and at heights up to 30ft above ground level. The instrument used for these measurements was a Dawe 1400 D Objective Sound Level Meter which was checked before and after each series of tests against a standard acoustic calibrator. The results are summarised below :

Noise Levels Measured on 300kVA Transformer, 11000/433V, 50c/s, 3-Phase

Transformer in open space	64·5dB
Noise level adjacent to enclosure with transformer inside	43·5dB
Maximum noise reading at any distance up to 20ft above ground...	44dB

To allow for background noise all these readings were taken at 40dB weighting. As might be expected background noise constituted a major difficulty. Tests were repeated on Sundays, week-day evenings and between midnight and 2 a.m., but at no time was the background noise level much lower than 40dB.

Consistent reductions of 16dB were obtained and at no point about 20ft from the enclosure could the transformer noise be heard irrespective of the height of the observer's position above ground. Noise measurements made around the rim of the enclosure at heights up to 6ft above the rim gave a reduction of 8 to 10dB compared with readings taken at points inwards and level with the rim. These results indicate that the open-topped circular enclosure exerts a funnelling effect on the sound waves rising from the transformer.

Further studies of such enclosures are being undertaken by Transformers (Watford) Ltd. in conjunction with the parent company. The matters being investigated include means for removing the transformer from the enclosure, the arrangement of cable entries, and access to the enclosure for testing and maintenance of instruments, tap-changing gear and other components.

The present state of this development can be summarised as follows. For distribution transformers up to 500kVA an 8ft diameter enclosure would accommodate a switch and feeder pillar unit. A ladder would give adequate access and a door in the brickwork would not be necessary. For larger transformers (fitted with Jansen on-load tap-changers) typical sizes of enclosure would be : 10MVA, 16ft diameter ; 15MVA, 19ft diameter ; 20MVA, 21ft diameter. With a rectangular tank there would be adequate working space at the ends and sides provided the diameter of the enclosure was made sufficient to allow the crew to negotiate the corners of the tank. Cavities would be provided in the brickwork to take pipes and fittings, thus enabling the cooler to be sited outside the enclosure. For the larger enclosures access doors would have to be provided as required. Clay tile copings are available for the top of the enclosure ; alternatively concrete copings could be used.

[Reply Card No. 1412]

Printing Machinery Exhibition

DURING this month an exhibition was held at the works of the Heidelberg Printing Machinery Company, Ltd., Eyot Gardens, Hammersmith, London, W.6, to demonstrate how press design is keeping pace with the evolution of new printing plates and processes. Among the exhibits was the Heidelberg two-colour 15in by 20½in litho-letterpress machine, in which direct impression from a cylinder carrying the litho plate can be combined with impression from a normal flatbed forme to cover a variety of requirements, often enabling the letterpress printer to undertake jobs which have been tending to go to other methods of production. This combination of rotary and flatbed printing has been developed from a previous Heidelberg flatbed machine to which a rotary printing cylinder, carrying a curved-plate forme, was added to allow two-colour printing in one run.

In the litho-letterpress machine a similar mechanical arrangement is adopted, with the addition of the damping system for the litho plates. The rotary cylinder prints direct on to the sheet instead of via a blanket cylinder as in the usual litho process. Typical applications of litho with letterpress are forms and catalogues, the tabular rules and diagrams being printed from the litho plate and type matter from the flatbed forme. The same combination can produce two-colour printing in one operation. As an alternative, the rotary cylinder can carry curved printing plates of the numerous kinds now available, or photo-engraved "wrap-around" plates made from mixed formes of type and blocks. Only two simple adjustments are required to cut out the action of the rotary cylinder or flatbed forme, and *vice versa*.

All cylinder presses at the exhibition, some of which are illustrated, incorporated the characteristic Heidelberg principle of a quick return stroke for the printing forme, which reduces the size of the cutaway portion necessary in the cylinder to prevent contact between forme and cylinder on this stroke, while allowing maximum use of cylinder area on the printing stroke. The smaller machines have star-delta starters and variation of printing speed by means of an adjustable pulley with handwheel control. In larger sizes the motors have rotor resistance starters, with fan cooling of the resistances so that these can be used for speed control when necessary. The cooling air is also used in the delivery systems of the machines.

[Reply Card No. 1394]

Fourth I.E.A. Exhibition

THE fourth International Instruments, Electronics and Automation Exhibition will be held at Olympia, London, from May 28 until June 2, 1962, will once again be the world's greatest display from this ever expanding industry. Nearly five hundred firms, many of them from overseas, will show instruments and electronic equipment, from complete computers to very delicate measuring devices. A feature of the 1962 exhibition will be the greater number of large stands, the individual stand space having increased on average by 20 per cent. This will ensure a finer display of the world's most up-to-date and reliable scientific instruments and electronic equipment in first-class conditions. Industrial Exhibitions Ltd., estimates from enquiries already received that the record-breaking overseas attendance of 4000 visitors in 1960 will be exceeded, as well as the home attendance of more than 70,000 visitors.

Service Trials of Ground Effect Machines

As is well-known the development of ground effect machines has, in this and other countries, been of particular interest to the fighting services ; such craft might be able to make a significant contribution to the execution of anti-submarine and amphibious warfare and in the logistic support of army units. In addition, they might be used in other roles including air-sea rescue, mine hunting and coastal forces duties. In order to assist in the evaluation of hovercraft in the military role, it is necessary to carry out sea trials. The Admiralty has given approval for an inter-Service hovercraft trials unit to be set up in H.M.S. "Ariel" at Lee-on-Solent. The aim of these trials will be to provide information to assist in determining the possibility of using hovercraft for military purposes, and also the formulation of staff requirements.

The nucleus of the inter-Service trials unit has already been formed and the slipway and airfield at H.M.S. "Ariel" are also being made available for use by experimental hovercraft constructed by industry. Some of these craft are, therefore, likely to be seen operating in the Lee-on-Solent areas shortly.

Flatbed printing machines with second-colour cylinder (foreground) and direct-printing litho cylinder (second from right)

SHORTER REPORTS *(Continued)*

Mangla Dam, Pakistan

On November 15 last a formal opening of the tenders for the Mangla dam in West Pakistan took place at the Caxton Hall in London. A public opening of the tenders was requested by the World Bank because "it ensures fair play and makes everything aboveboard." The dam is a key project in the vast irrigation proposals planned in the Indus basin. This, in its turn, depended upon the Indus Water Treaty which was signed by India and Pakistan last year. An explanation of the treaty and the schemes which depend upon it—schemes which promise to be some of the largest and most interesting which will challenge the civil engineers of the world during the next decade or two—was given in THE ENGINEER of of December 9 last, pages 990–91.

The consulting engineers for the Mangla scheme are Messrs. Binnie, Deacon and Gourley in association with Messrs. Preece, Cardew and Rider and Harza Engineering International of Chicago. Originally eight consortia applied to tender for the dam, but four subsequently withdrew, and so the tenders of the four remaining organisations were opened on November 15. The following overall cost figures were then announced, as shown in Table I.

TABLE I

Consortium	Contract figure	
	Rupees	£ million (approximate)
Guy F. Atkinson	1,685,534,652	126½
Utah Construction and Mining Company	1,812,471,359	136
Morrison-Knudsen International	1,783,331,549	134
Mangla Construction	2,196,491,097	165

£1 = 13·33 rupees. $1 = 4·75 rupees.

The first-named consortium has seven member companies, all of them American. The second comprises nine companies, three American, one Canadian, four French and one British (Taylor, Woodrow is the British member). The third-named comprises eight companies, five American, one French and two British (John Laing and Co. Ltd. and George Wimpey and Co. Ltd. are the British ones). The last-named comprises seven companies, one Danish, two American, one French, one Canadian, and two British (Holland and Hannen and Cubitts Ltd., and Gamma (Pakistan) Ltd.). It is expected that the award of the contract will be announced by the Water and Power Development Authority of West Pakistan in January. Some details of the Mangla scheme itself are given hereunder.

THE MANGLA SCHEME

The principal structures to be built are three earth dams, the spillway structure, five tunnels, the power station, and the tailrace and 3 mile long canal. Some principal quantities are given in Table II. The power station will have initial and ultimate installed capacities of 300MW and 1000MW respectively.

TABLE II—*Total Quantities of Work and Materials*

Excavation	95,000,000 cubic yards
Tunnelling	9500ft of 30ft diameter concrete-lined tunnels
Embanking materials	108 million cubic yards
Concrete	1,800,000 cubic yards
Cement	320,000 tons
Reinforcing steel	39,000 tons

The project is situated near the small village of Mangla where the River Jhelum emerges from the Himalayan foothills into the plains of West Pakistan. The present canal system in this part of Pakistan has been developed entirely from river flow without reservoir storage and in consequence irrigation supplies are precarious to the extent that they are subject to seasonal and yearly variation in river flow. With the Mangla reservoir providing storage, the water available for irrigation in this area will be nearly doubled. An additional benefit arising from the scheme will be the production of hydro-electric power.

The principal structures to be built at Mangla are three earth dams of maximum height 370ft, totalling 6¼ miles in length and requiring a total quantity of embanking material of 108 million cubic yards. The rate at which this embanking material is placed at one stage of construction will be quite unprecedented—something like 2,000,000 cubic yards per month.

The reservoir which will be created by these dams will be 40 miles long and 100 square miles in area. Careful arrangements are already in hand to resettle elsewhere the 70,000 people who are at present living in the part of the Jhelum valley which will be affected by the filling of the reservoir. The spillway structure will be capable of passing an exceptionally large flow—over 1,000,000 cusecs

During construction of the main dam the river will be diverted through five tunnels, each 30ft in diameter. These tunnels will subsequently be used to convey water to the turbines and for releasing irrigation water.

For the past 3½ years an intensive study of alternative designs has been made by the consulting engineers to find the most economic arrangement, consistent with safety and operating requirements, for the main works. Concurrently at the site, topographical, geological, hydrological and seismic surveys have been proceeding; 600 exploratory drill holes have been put down, and a 600ft trial length of tunnel has been driven. Construction should start next year and will take seven years to complete.

History of the Oil Engine

THE year 1961 may be considered as the centenary of the internal combustion engine, since it was in 1861 that the four-stroke cycle was conceived by Otto in Cologne after experimenting with a gas engine in which the charge was burnt without prior compression. Accordingly Shell-Mex and B.P. Ltd. has carried out an extensive research into the history of the oil-burning engine, in the course of which many early contemporary records not normally accessible to the public were examined. The highlights of this research are now being presented by the firm in two main forms, a book and a short film. The film contains no technical information, being based on contemporary pictures of the inventors and their surroundings, although it includes glimpses of important patent specifications. The book covers the history of the engine and its lubricant, and consists very largely of reproductions of contemporary drawings, specifications, or photographs; unlike the film, it contains sufficient explanation for a reader without expert knowledge to follow the course of developments.

The film, on loan, and copies of the book are available on application to the Public Relations Office, Shell-Mex and B.P. Ltd., "Shell-Mex House," Strand, London, W.C.2.

Completion of Hammersmith Flyover

THE accompanying illustration shows a length of the Hammersmith flyover, in London, which was formally opened to traffic by the chairman of London County Council on November 16. The illustration well shows the slenderness and structural form of the flyover, a description of which was published in THE ENGINEER of February 17 last, page 240.

The flyover has sixteen spans which extend over 2043ft, but the approach ramps bring its total length to 2381ft. Most of the spans have a dimension of 140ft. It carries two 24ft carriageways, and its overall width is 61ft. The carriageways have cables embedded in them which allow electrical heating to prevent the formation of ice. The safety fences are reputedly crash-proof, and have, on test, successfully withstood the impact of a 15-ton vehicle travelling at 30 m.p.h.

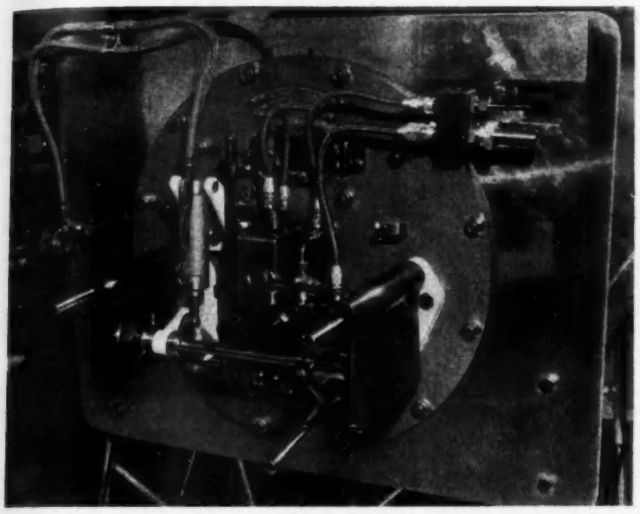
The flyover was designed by the consulting engineers Messrs. G. A. Maunsell and Partners, in collaboration with the chief engineer of London County Council, Mr. J. Rawlinson. The main contractor was Marples Ridgway and Partners Ltd., and the cost £1,033,000.

Hammersmith flyover: the precast elements forming the spine beam with precast cantilevers interposed, and the centrally-placed cast-in-situ columns can all be clearly distinguished. The mortar joints between the precast elements have been slightly recessed, to give the architectural effect shown in this view. Stranded wire cable has been used to apply the prestress, and the structure is continuous with only one expansion joint, the columns being on rollers

Marine Oil Burner

A NEW marine oil burner known as the "Wallsend Steam Assisted Pressure Jet" has been developed by the Wallsend Slipway and Engineering Company Ltd., and has been fitted to the three 65,000 ton deadweight tankers "Serania," "Sepia," and "Solen" built for the Royal Dutch/Shell Group. In this new system of oil burning the steam-assisted pressure jet is shown to its full advantage by its ability to operate over a much wider range of output than the normal pressure jet burner and its adaptability to automatic combustion control.

With the simple pressure jet the turn down is limited since the throughput of oil varies as to the square root of the oil pressure. In addition to this, it is normal not to drop below 150 lb per square inch oil pressure, as the spray particle size is then too large for good combustion. Therefore, for oil pressures between 450 lb per square inch and 150 lb per square inch the turn down is limited to 1·7 : 1. If the lower oil pressure can be extended down to 4·5 lb per square inch the turn down will then be 10 : 1 and to maintain atomisation at these very low oil pressures the burner has been developed to utilise steam. The burners are designed so that they may be operated with or without steam atomising up to their maximum output without changing the burner gun or nozzle, and if steam is required all that is necessary is to open the master steam supply valve, leaving the burner in operation the whole of the time.



Steam assisted pressure jet marine oil burner

The photograph shows a burner of this design with an additional air-operated cylinder for remote on/off control. It is not possible to have oil passing to the burner without the forced draught air sleeve being fully open and the burner gun cannot be removed without first shutting off both oil and atomising steam, in accordance with Lloyds Regulations. If the burner gun is not in the block, and the air slides are accidentally put into the fully-open position, it is so arranged that no oil can flow. A steam purge valve is fitted to discharge any oil remaining in the burner gun prior to shut down and subsequent removal. If the boiler demand drops below the turn down ratio of the burners it may be necessary to shut off one fire. In this instance the air supply is shut off thus closing the oil supply, but the steam atomising remains on and acts as a coolant for the burner gun tip.

Due to the low steam flow requirements, owners have elected to maintain steam atomising when "Full Away" as well as for manoeuvring conditions. Experience in service indicates that these burners may be left in the boiler for long periods without any deterioration in performance. The problem of controlling the air supply for wide range burners has been simplified by most of the range having a single oil and air flow characteristic. The air director has been designed to be of the suspended flame pattern having inherent flame stability at extremely low register draught losses. This flame stability is of advantage when air/fuel ratios may be changing rapidly due to automatic combustion control equipment having to follow rapid changes of load.

The combustion control system is arranged so that hand trimming can be applied to allow for alterations in operating conditions.

[Reply Card No. 1414]

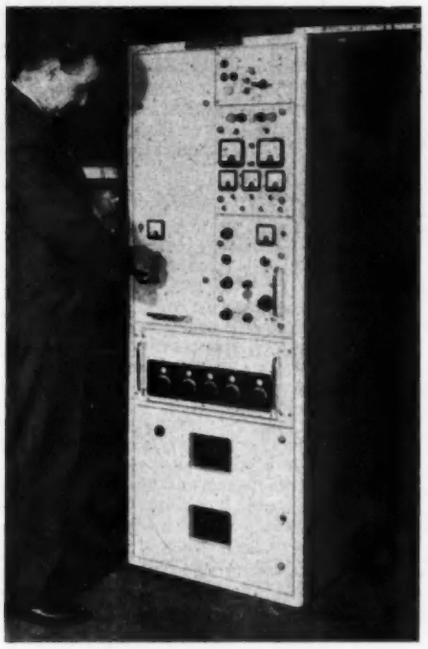
Independent-Sideband Transmitter

WE illustrate the prototype NT204 500W communications transmitter of Marconi's Wireless Telegraph Company Ltd., Chelmsford, Essex, numbers of which are to be supplied to the Admiralty for shipboard use with the Royal Navy, together with external master oscillators and aerial matching units. This is believed to be the only transmitter to provide continuous tuning throughout the maritime m.f. and h.f. bands, namely from 240 kc/s to 24 Mc/s, in one small, compact equipment. The final stage uses the Marconi distributed amplifier technique (THE ENGINEER, August 21, 1959, page 112) and requires no tuning. Range-switching of the two-stage drive amplifier takes place automatically by means of "Ledex"-driven switches when the "Megacycles" selector switch of the synthesiser unit is operated. This unit provides spot frequencies at intervals of 0·1 kc/s from an external Marconi N7020 master oscillator operating at 1 Mc/s. The transmitter output may be c.w. or m.c.w. telegraphy (keyed at 30 bauds), or independent-sideband (telephony or v.f. telegraphy).

Dimensions of the deck-mounting cabinet illustrated are 5ft 4in by 1ft 11¾in by 2ft 3in. It houses the frequency synthesiser, sideband generator, and r.f. power amplifier stages, with power supplies. The master oscillator, air-cooling supply and aerial matching units are external, the latter normally being installed remotely. The frequency synthesiser is a completely transistorised unit with its own power supply. It accepts a 1 Mc/s input from the external master oscillator, and a composite modulated signal centred on 100 kc/s from a sideband generator incorporated in the NT204. The 1 Mc/s control frequency is subjected to processes of multiplication and division, and selected frequencies thus derived are synthesised with the 100 kc/s intelligence-bearing signal to produce the required radiated frequency. The resultant output, which is at a level of 10mW, can be any frequency which is a multiple of 100 c/s within the total range 240 kc/s to 24 Mc/s.

The five controls seen on the front panel of the frequency synthesiser in the illustration operate rotary frequency-selector switches and are directly calibrated in terms of radiated frequency in steps of 1 Mc/s, 100 kc/s, 10 kc/s, 1 kc/s and 0·1 kc/s. The unit also delivers a 100 kc/s carrier to modulators contained in the sideband generator unit. Provision has been made in the design for the shared feeding of a number of frequency synthesisers from a common master oscillator.

The sideband generator is also completely transistorised and extensive use is made of printed wiring boards. Its function is to provide the 100 kc/s composite modulated signal for use in the frequency synthesiser described above. To this end it embodies two separate channels each incorporating an a.f. amplifier, volume compressor and speech clipper, 100 kc/s balanced modulator and sideband filter. Each channel is also fitted with a sidetone amplifier.



Operating the single-output tuning control of a marine transmitter with unbroken coverage from 240 kc/s to 24 Mc/s. Frequencies are selected at 0·1 kc/s intervals by the five rotary switches on the panel below

The 100 kc/s sideband output from each balanced modulator is routed through the appropriate upper or lower sideband filter for i.s.b. working (or *via* an attenuator for d.s.b.) to a combining circuit, where the outputs of the two channels are integrated. The combined signal is then applied to a 100 kc/s buffer amplifier to provide the "intelligence" drive to the frequency synthesiser. Arrangements are also made in this amplifier for re-inserting the carrier for c.w., m.c.w., d.s.b., and i.s.b. pilot carrier conditions.

The two units of the r.f. amplifier are the drive amplifier and the broadband final power amplifier. The former covers the radiated frequency bands in nine tuning ranges. On the lowest frequency range no tuning is employed, but on the others three circuits are tuned by a three-gang variable capacitor controlled from the front panel. This is adjusted for maximum reading on an r.f. drive level meter. Input to the drive amplifier is of the order of 10mW, and the output is approximately 5W p.e.p.

The final amplifier employs six pairs of 4X250B air-cooled tetrodes in a push-pull distributed amplifier circuit working under class AB1 conditions. Separate output transformers for m.f. and h.f. are used, the appropriate units being brought into circuit (above and below 3 M/cs) automatically by the operation of the "Megacycles" selector switch on the frequency synthesiser.

The h.t. supply unit provides supplies for all the r.f. stages. It comprises a silicon rectifier bank and smoothing, h.t. regulation and distribution circuits. The rectifier bank consists of three separate three-phase full-wave rectifier systems, each having twelve SX754 rectifiers connected in six series pairs. Voltage sharing is obtained by capacitor division, and a p.i.v. safety factor of greater than 2 : 1 is achieved.

[Reply Card No. 1388]

SHORTER REPORTS *(Continued)*

International Standards Committee on Cranes

A NOTE received from the British Standards Institution points out that most countries (including the U.K.) have standards for cranes, and at present difficulties arise with the export of cranes from one country to another due, in particular, to the varying methods adopted for rating cranes in respect of their safe working loads. As a first step towards unification of these conflicting standards there has been set up by the International Organisation for Standardisation a new technical committee on cranes and excavators. This committee, which has just concluded its first series of meetings, is concerned particularly with terminology, load rating, materials, design, stability, testing and safety.

In the course of these meetings, delegates from Finland, France, Germany, the Netherlands, Poland, Portugal and the U.K. were primarily concerned with reaching agreement on definitions of fundamental technical terms. In addition, proposals made for a standard range of capacities for cranes were considered and will be further discussed at a future meeting. Other matters to which the committee will give priority are : stability requirements for cranes (including consideration of wind loads) ; testing procedures for cranes ; crane ropes and associated pulleys, drums, &c. ; and crane structures. When these fundamental points have been dealt with, the committee is to consider the establishment of working groups to deal with builders' tower cranes, jib cranes, overhead travelling and bridge cranes, mobile cranes and single bucket excavators.

Concrete Batching and Mixing Machine

WE recently attended a demonstration of a concrete batch mixer which has been added to the contractor's plant marketed by the construction equipment division of British Jeffrey-Diamond Ltd., of Wakefield. The machine, which incorporates a skip loading equipment, has a wet mix capacity of 7 cubic feet, and its mixing cycle is stated to be well under a minute for each complete batch. It can, if required, be supplied complete with weighing equipment, a power driven loading scraper and a feed wall, as shown in the photograph we reproduce on this page. When working in conjunction with this optional equipment the mixer can attain an hourly output of 530 cubic feet.

A particular point in the design of the machine is the ease with which it can be transported on its pneumatic tyred wheels and the speed at which it can be prepared for operation on site. Using the feeding installation shown in the illustration, a barrier wall is erected and the sand and aggregates tipped into segments on one side. A winch-driven, hand-guided scraper shovel is used to haul the aggregates to a central point at the top of the wall so that they are deposited by gravity into small feed hoppers delivering into a common central chute. A hand-lever-operated gate at the foot of each feed hopper is used to deliver the required amounts of aggregates into the batching skip of the concrete mixer situated in front of the wall. A portable silo can be conveniently sited to feed the cement into the batching skip.

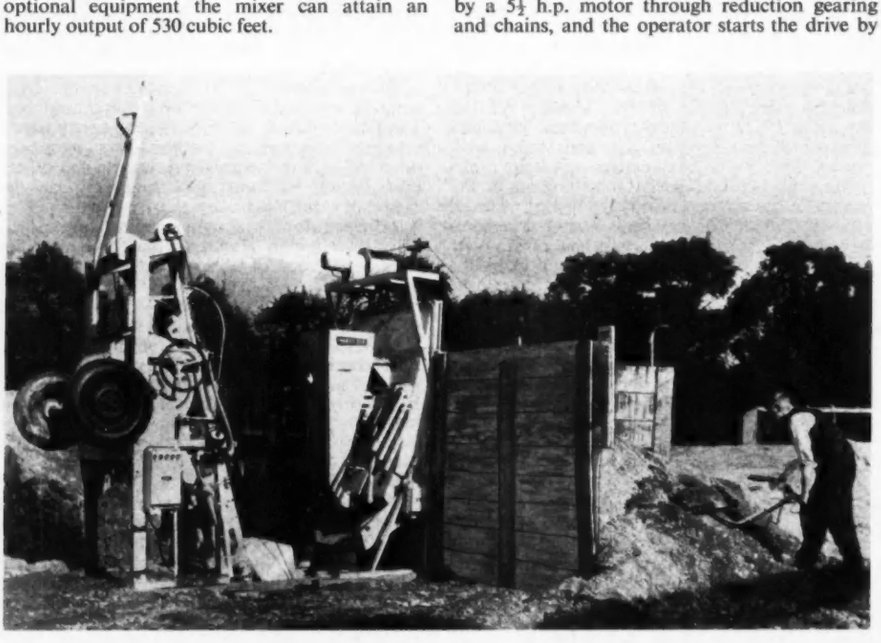
The working cycle of the mixer is controlled by a single operator from a push-button panel at the side. The mixer is built into a rigid fabricated steel section frame with two vertical front columns and having inclined rear columns which form runways for the skip carriage. When the skip is in its lowest position below the loading chute its weight is taken through a protected lever system to an integral weighing equipment when the machine is so fitted. As the aggregates, sand and cement are in turn delivered into the skip their weights are progressively registered on a large dial fitted with adjustable pointers indicating the individual feed increments.

When a batch of materials has been loaded into the skip a push-button is depressed and a 3 h.p. motor-driven winch driving through a pulley shaft at the top of the frame hauls the skip up its runways. As the skip nears the top of the frame it is swung over to discharge the load into the mixer drum by the lower wheels of its carriage riding up curved tracks welded on the mainframe, a limit switch being contacted to stop the drive at the fully tipped position of the skip. The return of the skip to the loading position is again push-button controlled. A solenoid-operated brake is fitted to arrest the motion of the skip in the event of a failure of the electric power.

The mixer drum, which is stationary during the mixing period, is a simple horizontal sheet steel cylinder with a large filling and discharge opening along its full length. A shaft along the axis of the drum carries a scroll and has three sets of paddle arms spaced along its length. At their outer ends the paddle arms are fitted with blades which sweep round the wall of the drum outside the scroll. The shaft is driven at 32 r.p.m. by a 5½ h.p. motor through reduction gearing and chains, and the operator starts the drive by depression of a switch when drum filling has been completed. At this point water, taken directly from the mains, is admitted into the top of the drum by opening a valve and controlling the amount with reference to a flow meter dial.

During the mixing operation the scroll impels the concrete in one direction along the inner part of the drum ; material which is moved outwards during this longitudinal movement and at the end of the drum is picked up by the paddle arm blades. These blades are set to the opposite pitch of that of the scroll. With this arrangement the concrete is moved in a complex but controlled spiral motion in opposite directions, being agitated at the same time by the scroll and paddles.

At the end of the mixing period—which can be as low as twenty seconds—the operator releases a locking lever and the drum automatically swings over to discharge the material. This turning movement is effected without manual effort as the drag of the mix on the drum sides gives sufficient power to rotate it. The height of frame mounting of the drum is such that when it has turned through 180 deg. its opening is 4ft above ground level, high enough to permit the introduction of dump trucks for removal of the mix. After discharging, the operator releases a locking lever and the drum automatically returns to its original position ready to receive the next charge.



Batch mixing machine with weighing equipment, loading scraper and feed wall

Extinguishant for Metals

BECAUSE such metals as uranium, plutonium and especially thorium are pyrophoric in a finely divided state, the United Kingdom Atomic Energy Authority has taken particular interest in the extinguishing of burning metals. Both because the oxides of plutonium and uranium are toxic and because the metals are expensive, rapid extinction is at a premium. There has been evolved a medium consisting of dry powdered inorganic chlorides and/or fluorides inert towards the metal involved ; the mixture, being eutectic, melts at a temperature below that at which the metal concerned melts, and hence the heat of combustion is absorbed as latent heat by the powder. The molten chemical spreads over the surface of the metal and excludes air from it ; since the powder does not include oxygen, the metal cannot react with it, as does, for instance, magnesium with a water-based blanketing foam. Large-scale practical trials of ternary eutectic chloride powder as an extinguishant have been carried out on such subjects as an aircraft with magnesium wheels, and the wheels were extinguished not only quickly but, it is claimed, easily, without needing the whole of a 35 lb charge.

To safeguard materials being machined or worked within glove boxes, it is recommended that each glove box contain a flat polythene-wrapped pack of 2 kg ternary eutectic chloride powder, to apply as a first aid measure to any fire. For large glove boxes or storage caves systems distributing powder from nozzles under gas pressure have been evolved by John Kerr and Co. (Manchester) Ltd., who manufactures the powder under licence from the A.E.A. As produced by the company, the powder has a melting point of 580 deg. Cent. and a moisture content of less than 0·3 per cent ; it is supplied in bulk, i.e. packed in drums.

[Reply Card No. 1391]

International Boat Show

THE 1962 International Boat Show, which is sponsored by the *Daily Express* in association with the Ship and Boat Builders' National Federation, will be opened at Earls Court, London on January 3 and close on January 13. More than 450 exhibitors will be taking part and exhibits will include:—the C.C.2 "Cushioncraft," designed and built by Britten-Norman Ltd. ; a yacht hull constructed of "Seacrete" shown by Windboats Ltd.; and a Shell Mex and B.P. floating filling station.

Treatment of Phthalic Anhydride Tail Gases

PHTHALIC anhydride is manufactured by the controlled catalytic oxidation of naphthalene or ortho-xylene with air under pressure, and after recovery of the crude product the residual tail gases, which consist of nitrogen containing 12 to 15 per cent oxygen and organic contaminants, are discharged to waste. The organic content is usually of the order of one grain per cubic foot, and consists of carbon monoxide, phthalic anhydride, maleic anhydride, aldehydes, naphthaquinones and traces of other complex organic compounds. The tail gas also contains sulphur originally present in the feedstock, and being lachrymatic and odourous is not fit for direct discharge to atmosphere. The contaminants are not all present in the gas or vapour phase; some exist as aerosols, and some as particulate material of a resinous nature.

Tail gas catalytic treatment plant

The composition of the tail gas depends upon the feedstock used, the operating conditions, and on the catalyst used. In the first phthalic anhydride plants little or no attempt was made to ameliorate the quality of the tail gases discharged to atmosphere, but as the size of manufacturing units increased the need for some form of fume correction was apparent.

Many methods have been tried to correct the fume nuisance, but until the introduction of catalytic combustion techniques the problem was not solved. The scope of the problem is shown by the fact that one authority suggests that the maximum concentration of aldehydes present in the mixture should not be more than forty parts per 1,000,000 to produce an acceptable effluent, and that sixty parts per 1,000,000 would not be tolerable. Prior to the introduction of catalytic combustion the usual treatment was wet washing, and generally the aerosol content of the fume was unchanged. Although the compounds giving rise to odour and lachrymatory effects were reduced in quantity the tail gases were still objectionable.

The Catalytic Combustion Corporation introduced in the United States the method of treating these tail gases by combustion using catalytic techniques. In catalytic combustion carbon dioxide and steam are produced from the combustible organic contaminants, and any sulphur content is discharged as sulphur dioxide. The quantity of sulphur present is usually low, and so does not present an air pollution problem. The resultant gases are colourless and do not contain any appreciable odour or lachryma content.

The Catalytic Combustion Corporation catalyst is used in the Holmes Catalytic Plants, manufactured in this country by the Chemical Engineering Division of W. C. Holmes and Co. Ltd., and is of all-metal construction, and resistant to mechanical and thermal shock. The catalyst has high thermal conductivity coupled with low heat capacity, so that temperature response is very rapid. It is made up of separate elements which are supplied in two sizes ; the smaller will treat 320 s.c.f.m., and the larger will treat 700 s.c.f.m. The requisite number of these elements are arranged side by side in a supporting frame, and the catalyst has a long life, usually in excess of 30,000 hours. The heat resisting/corrosion resisting metal support accounts for a high proportion of the catalyst cost so that they have a high reclaim value, and can be used again after treatment. This regeneration process costs about 40 per cent of the original new catalyst price, and can be carried out a number of times before the support is no longer suitable for re-use.

The tail gases produced have a relatively low organic content and hence energy content. The energy content depends upon the source of the gas, and is often less than 2 B.Th.U's per cubic foot. In normal combustion practice it is necessary to heat these gases to about 1400 deg. Fah. to ensure efficient combustion, and efficient fume nuisance removal. By using catalytic combustion it is possible to reduce the temperature to which the fumes need to be heated to between 700 deg. and 750 deg. Fah., and by incorporating a heat exchanger the fuel requirements are further reduced.

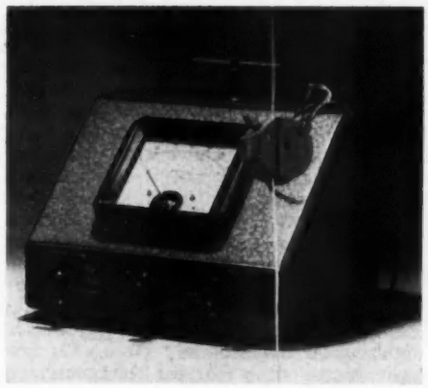
In the plant shown in the illustration, and installed at the Totton Works, Southampton, of South Western Tar Distilleries, the tail gases are passed through a tubular heat exchanger and then into a combustion chamber containing an oil burner, where the gases are finally heated to catalytic reaction temperature. The mixture of tail gas and hot burner flue gases is drawn into a centrifugal fan and discharged over the surface of the catalyst where combustion of the objectionable constituents takes place. Before discharge to atmosphere the oxidised gases pass to the heat exchanger to preheat the incoming tail gases. The discharged gases are free from colour and are virtually odourless. To ensure automatic and safe operation the plant is fully instrumented, and an alarm system gives warning of any faulty operation.

[Reply Card No. 1411]

Electronic Wire Feed Speed Monitor

IN consumable electrode welding, where the rate of feed of the electrode wire has a critical influence upon the quality of the joint produced, the usual method of determining feed speed is by direct tachometer reference to the speed of the drive rolls. This method is susceptible to inaccuracy as the result of wire slip, according to the British Welding Research Association which has now developed the monitoring instrument we illustrate. This instrument is independent of the feed rolls and produces a signal capable of reproduction either on an oscilloscope or as a direct " inches per minute " meter reading.

In the instrument the wire itself drives a milled spindle to the end of which is attached a disc having regularly spaced slots around its periphery. The disc is positioned between a small lamp and a photo-electric cell and as the disc rotates the light beam is interrupted and the electrical resistance of the cell alternates accordingly, the cycles taking place seventy-two times with each revolution of the driving spindle. The change in electrical resistance, applied to a transistorised amplifying circuit, produces a square wave output signal which is fed into an electric frequency meter coupled to a direct reading " inches per minute " scale.



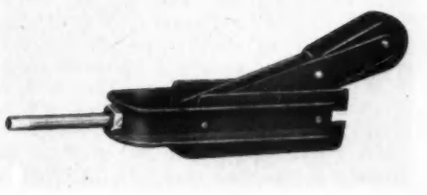
Feed speed monitor for electrode wires up to ¼in diameter

To give maximum accuracy the instrument is calibrated for 0–30in, 0–300in, and 0–600in per minute, the entire scale being used in each range which is selected by means of a switch. Since the value of the light energising the photo cell must remain constant a position is provided on the selection switch for measuring the output of the 6V battery supplying the lamp. A minimum value is indicated on the meter scale below which the accuracy of the instrument falls off, and this serves as a warning that the batteries should be replaced. The monitoring head itself is 3in diameter by 1in deep and is small enough to be incorporated into the drive roll housing of many commercially available wire feed units. It will handle wire up to ¼in diameter. An additional use for the monitoring instrument is in measuring traversing or rotating table speeds in mechanised welding operations.

Toggle Clamps

WE illustrate one model of a new range of quick acting toggle clamps, in which the ram movement is controlled in a straight line throughout its stroke of ¼in. These clamps are made by Speed Tools Ltd., Vereker Buildings, Greese Street, London, W.1, in both " push " action action and " pull " action models.

The spindle, adjustable for length, is locked on a " U "-shaped ram or slide on the body of the tool. This slide is guided in parallel twin slots in the body and is moved forwards through a toggle linkage by depression of the handle. When the handle is fully depressed and the toggle lock applied the overall height of the tool is only 2½in, and a load of about 150 lb is applied by the ram.



Push-action toggle clamp with straight-line ram movement

The " pull " action clamp of similar design applies the holding load when the handle is depressed. Clamps can also be supplied with the front of the rams fitted with a swivel bracket to which adaptors to suit particular classes of work can be fitted if required.

[Reply Card No. 1376]

INDUSTRIAL NEWS

T.U.C. and the "Pay Pause"

The Trades Union Congress has written to the Chancellor of the Exchequer, The Rt. Hon. Selwyn Lloyd, expressing its concern at current developments and warning that, unless corrective action is taken immediately, Britain's present unsatisfactory economic position will deteriorate still further. The Economic Committee of the General Council of the T.U.C. remains firmly of the view, the letter states, that the Government was in error in asserting that the economy was under undue pressure in the middle of the year, and fundamentally wrong in imposing the wages pause. During the first eight months of this year, the letter continues, hourly wage rates rose by about 2 per cent, compared with a 3 per cent rise in productivity ; in manufacturing industry they rose about 1 per cent compared with a 5 per cent productivity increase. In the same period, the letter adds, dividends increased by about 14 per cent. Nor have the Government's policies been justified by their effect on the balance of trade, the T.U.C. says, exports in the third quarter being barely above the second quarter and imports barely less, imports of manufactured goods having risen sharply.

The Committee have noted that the announced purpose of the reductions in Bank rate was to discourage the unhealthy inflow of short-team capital, the letter continues, and take the view that a further reduction in Bank rate is necessary not only for this primary purpose, but also for the sake of such effects as it might have on the level of internal economic activity.

To prevent a further weakening of Britain's economic position the Committee also considers that the Government should forthwith make a cut in the surcharge on indirect taxes, and terminate the wage pause which, the letter states, is not only disruptive of good industrial relations but is positively harmful in the present economic situation.

Industrial Relations

Mr. Harold Burke, president of the Institution of Production Engineers, emphasises in a statement issued last week that his recent suggestion regarding the appointment of a Minister of Production (THE ENGINEER, November 10) should in no way be regarded as supporting a policy of nationalisation. He is horrified, he says, at the very thought of any further nationalisation of British industry.

Mr. Burke goes on to say that he is, however, deeply concerned with the problem of human relations, and suggests that the present machinery for dealing with industrial disputes needs fresh thinking. It seems clear, he says, that the present arrangements between employers' federations and trades unions, with an intermediary from the Ministry of Labour, are not proving entirely satisfactory. In a modern democracy, Mr. Burke believes, it should be possible for employers and trades unions to discuss all their problems with a reasonable chance of reaching some agreement without stopping work, and he appreciates that this is always the object behind such discussions. There are, however, all too many occasions when this does not work out, and in such circumstances, Mr. Burke states, he feels that a panel of industrial advisors could make a major contribution in recommending terms of settlement.

On several occasions, Mr. Burke continues, the bar to settlement has been stubbornness on the part of certain individuals. He recognises that neither industrialists nor trade unionists would be willing to accept Government direction in the conduct of their affairs, but he suggests that this is mainly due to the fact that the average man in industry regards members of the Government as politicians or civil servants who do not understand the day-to-day problems of industry. It has to be recognised that there are industrialists in prominent positions in the Government, but, Mr. Burke maintains, an independent industrialist at a very high level is needed to guide future thinking on industrial relations.

Industrial Film

A new film which shows in great detail three complete handling schemes in such diverse installations as a plating plant, an egg-packing station, and a diesel engine factory, has been produced by Paul Barralet Productions Ltd., for Geo. W. King Ltd., Stevenage, Herts., makers of mechanical handling equipment for more than forty years. A "Stanrun" twin-rail overhead conveyor, carrying up to fifty different types of components from the store automatically through the various stages of plating, is shown in operation at the new plating plant of Vauxhall Motors Ltd. In the Peterborough diesel engine factory of the Perkins Group, a remotely-controlled "Marvex" electric chain hoist, a "Dual Duty" twin-rail overhead chain conveyor, an "Under-Tug" floor conveyor, a "Super-Track" overhead runway, and a King 58ft span double-beam overslung crane of 1½-tons capacity, are all shown working as part of an integrated system. At the Kenninghall egg-packing station of J. Sainsbury Ltd., which handles some 3,000,000 eggs a week, the film shows a "Stanrun" selective overhead conveyor which has been installed to help reduce manual handling to a minimum.

Wage Increase in the Electricity Supply Industry

The Electricity Council has announced that with effect from the first full pay period following January 28, 1962, all manual workers in the electricity supply industry will receive an increase in the grade rate of 2d. per hour. All manual workers with two years or more service on January 28 will be placed on a weekly wage consisting of forty-two times the revised grade rate plus an additional amount varying from 5s. a week for labourers to 8s. 6d. a week for installation inspectors. The Council points out that of the manual workers involved in this award 70 per cent are engaged in the distribution of electricity and 30 per cent in generation.

An increase of £2 a week per man was initially sought by the trade unions in a claim dating back to a meeting of the National Joint Industrial Council held on July 20, 1961, and on September 20, at a meeting of the Negotiating Committee, the unions submitted a statement in support of this claim. Members of the Central Electricity Generating Board undertook to give their reply to the unions' claim at the next meeting of the Negotiating Committee on October 18, 1961. On that date the Board's members, in rejecting the claim for an increase of £2 a week, offered improved weekly wages with an increase in earnings for established workers. At a later meeting on October 26 the Board's members made an improved offer based on increases for manual workers with a minimum of three years' service which would provide a further increment after a further two years' service, the amounts of each increment to vary with the grade of worker. They also offered a small increase in the basic wage rate.

This offer was rejected by the unions and negotiations were not resumed until November 15. On the following day, November 16, after more than eight hours of continuous negotiation, agreement was reached.

It has also been agreed that early in the new year the National Joint Industrial Council would consider the questions of productivity in the electricity supply industry and means of improving the states of the manual workers employed therein.

Selection and Training of Supervisors

The British Employers' Confederation has published its report to the Ministry of Labour Committee on the Selection and Training of Supervisors, as a supplement to the current issue of its *Bulletin*. The Confederation, which is represented on the Committee, summarises in its report the results of its enquiries into arrangements made by its members for the training of supervisors and indicates the extent of the facilities which have been developed. The report also includes information asked for by the Committee in regard to the recruitment and selection of supervisors.

In some industries, the report suggests, the difficulties over the recruitment of supervisors are connected with changes in the character of their responsibility which, with increasing mechanisation, is becoming more technical, while the job itself has also become more complicated because of changes in the organisational structure of many firms. It will become more difficult in future to fill adequately all supervisory posts by promoting persons from the shop floor, the report states, unless they have been prepared for promotion at a very early stage. To meet this difficulty it is also considered, the Confederation says, that more training schemes for apprentice technicians could create a valuable pool of trained persons who may eventually be capable of taking on responsibilities in either a technical or supervisory capacity.

In the great majority of the industries covered by its enquiries, the Confederation states, most firms in selecting supervisors normally attach greater importance to personal qualities of leadership than to technical qualifications.

In its conclusions, the Confederation reports that its enquiries have revealed that since the report of the Ministry's previous committee of enquiry, there has been amongst the industries within its membership a gradual and continuing expansion in the scale and extent of training provided for supervisors and potential supervisors.

PERSONAL AND BUSINESS

Appointments

MR. S. R. GRAY has been appointed Southern area sales manager for Cranes (Dereham) Ltd.

DR. D. L. OLDROYD has been appointed as head of the research division of Ampex Electronics Ltd.

MR. C. F. HEYWOOD has joined Andrews Bros. (Bristol) Ltd., to manage its new reinforced plastics department.

EDIBRAC LTD. has appointed Mr. Ernest Waterfall as manager of its main factory at Broadheath, near Manchester.

FORD MOTOR COMPANY LTD. announces the appointment of Mr. Victor G. Raviolo as director of engineering.

VOKES GROUP LTD. announces the appointment of Mr. F. V. Smith as director and general manager of its Scottish subsidiary company, Robert Kellie and Son Ltd.

MR. W. T. MARCHMENT, divisional manager of the instrumentation and controls division of Evershed and Vignoles Ltd., has been elected to the board of directors.

MR. W. H. SPENCER, A.M.I.C.E., has been appointed an assistant chief engineer to take up a new post in the motorways branch of the Ministry of Transport.

THE BRITISH IRON AND STEEL RESEARCH ASSOCIATION has appointed Mr. A. G. Shakespeare as head of its steelmaking laboratories at the Sheffield research station.

KETAY LTD.—a member company of the Plessey Group—announces the appointment of Mr. K. J. Coleman, A.M.I.Mech.E., A.M.I.E.E., A.F.R.Ae.S., as chief engineer.

MR. C. J. WEGERIF, who is a director of Dowty Rotol Ltd., and deputy managing director of Dowty Marine Ltd., has been appointed sales director of Dowty Rotol Ltd.

FERRANTI LTD. announces that Mr. Maurice C. Curties, A.F.R.Ae.S., has been appointed senior project engineer (V.T.O.L. systems) in the aircraft equipment department at Bracknell, Berks.

TURNER AND NEWALL LTD. announce that Mr. R. H. Wilson has been appointed a director of Newalls Insulation Company Ltd., a unit company of the Turner and Newall Group, as from January 1, 1962.

MR. W. E. A. REDFEARN, director of English Steel Corporation Ltd. and managing director of English Steel Forge and Engineering Corporation Ltd., has joined the board of Firth-Vickers Stainless Steels Ltd.

MR. J. E. ARMITAGE has been appointed comptroller of British Aircraft Corporation. He will continue, for a limited period, as commercial director of Vickers-Armstrongs (Aircraft) Ltd., which is a subsidiary of the Corporation.

MR. G. B. HALLEY, managing director of the Wallsend Slipway and Engineering Company, recently assumed overall co-ordinating control of the Wallsend Slipway and the engine works at the Neptune shipyard of Swan Hunter and Wigham Richardson Ltd., Walker-on-Tyne.

THE BRITISH MOTOR CORPORATION has announced that Mr. Alec Issigonis, chief engineer of B.M.C. since 1957, has been appointed technical director in succession to Mr. S. V. Smith, who has retired. Mr. Issigonis has also been appointed to the Board of the Austin Motor Company Ltd.

THE LONDON CHAMBER OF COMMERCE announces that Mr. F. H. Tate has been elected deputy chairman in succession to Mr. R. L. Wills, who has resigned owing to his heavy commitments as a member of Rochdale Committee. Mr. P. S. Henman has been elected to fill the office of treasurer vacated by Mr. Tate.

THE PLESSEY COMPANY LTD. announces the appointment of Mr. Robert Hall as divisional general manager of a total of four divisions and associate companies within the Plessey Swindon Group. These comprise the units and parts division and sheet metal unit of The Plessey Company Ltd., as well as Power Auxiliaries Ltd. and Machine Products Ltd.

STANLEY WORKS (G.B.) LTD. has appointed Mr. Ronald Shelton, product designer, to head a new department responsible for the design and development of new products. Mr. Robert Bradley, formerly chief planning engineer, has been appointed manager of the engineering department. Mr. Laurence Ford, chief engineer, is leaving the company to take up a new appointment.

Business Announcements

CROMPTON PARKINSON ELECTRICAL LTD., Brantford, Ontario, Canada, has taken over the sales of Aeroflex fuse-links designed to Canadian standards by Parmiter, Hope and Sugden Ltd., Manchester.

TELCON PLASTICS LTD., Farnborough, Kent, is reopening on December 1 the branch in Cardiff at 16-17, Hills Terrace, previously operated by The Telegraph Construction and Maintenance Company.

RIMER MANUFACTURING COMPANY LTD., Melingriffith Works, Whitchurch, Cardiff, has concluded an agreement with Esso Research of America to manufacture under licence the heatless absorbtion air dryer.

AIRTECH LTD., Haddenham, Bucks, and CHARTAIR LTD. have been merged, all the undertaking, assets and business of Chartair Ltd. having been acquired by Airtech Ltd., whose capital has now been increased to £250,000.

MR. HAROLD DIGGLE, M.I.E.E., consultant for the engineering department at the Wythenshawe works of Associated Electrical Industries Ltd., Transformer division, has retired after forty-six years' service.

THE LAMBRETTA/TROJAN GROUP OF COMPANIES, Croydon, Surrey, has formed a new subsidiary known as Trogian Italiana S.a.s., Via G. Fara 39, Milan, Italy, to deal with its export/import business with the Continent.

VAUXHALL MOTORS LTD. has announced that Mr. F. V. Barker, a director of the company since 1955, will resign from the board at the end of November, when he will be retiring from Vauxhall Motors under the terms of the company's retirement programme.

COMBUSTION CHEMICALS LTD announces that John Thompson (Australia) Pty Ltd., has been appointed agent for Australia and New Zealand for Desulfurol sulphur inhibitor and fuel improver and other products in the C.C.L. range of fuel treatments and combustion additives.

STANDARD TELEPHONES AND CABLES LTD. has announced its intention to establish a new factory at Monkstown, Northern Ireland, and plans to occupy immediately an existing new building of 50,000 square feet to provide facilities for training factory operatives and to start production.

BAKER PERKINS GRANBULL LTD. states that its sales office has been moved to 4-6, Edwin Road, Twickenham, Middlesex (telephone, Popesgrove 1293). The administration, accounts, &c., will continue to be run from Baker Perkins Granbull's works at 39, High Street, Kingston-on-Thames.

THE EMBASSY MACHINE AND TOOL COMPANY LTD., 248, Watford Way, Hendon, N.W.4, has been appointed representatives for Model Trimmer Incorporated of Columbus, Indiana, U.S.A. This firm, which has specialised in the manufacture of trimming machines for many years, has just added a new machine of 150 tons capacity to its range.

THE BRITISH ALUMINIUM COMPANY LTD. and the NORTH OF SCOTLAND HYDRO-ELECTRIC BOARD jointly announce that, in accordance with an agreement reached some months ago, the board will supply the company with large blocks of power from the Highland grid when needed. This arrangement will help the company to maintain a steadier load for operations at its Lochaber and Kinlochleven aluminium smelting works, and the diesel generating equipment previously contemplated will not now be installed.

EDGAR ALLEN AND CO. LTD. announces that, having held a minority interest in the capital of the Sheffield Hollow Drill Steel Company Ltd. for many years, it has now acquired the remainder of the issued capital, and the company now becomes a wholly-owned subsidiary within the Edgar Allen Group. Mr. W. Duncan Howe and Mr. Douglas Howe, who have been responsible for the management of the company for many years, have been appointed general manager and deputy general manager respectively. The board of the subsidiary company will comprise Mr. F. A. Ross, chairman, Mr. W. Duncan Howe, Mr. Douglas Howe, Mr. W. G. A. Jenkins. The secretary will be Mr. J. Schofield.

Contracts

THE ENGLISH ELECTRIC COMPANY LTD. has received the order to build the 1450 s.h.p. twin-screw, diesel-electric propulsion machinery for the District Tender vessel which is to be built by J. Samuel White and Co. Ltd. The installation will consist of four six-cylinder engines driving d.c. generators and two 725 s.h.p., 460V 228/205 r.p.m. propulsion motors.

THOMAS SUMMERSON AND SONS LTD., Mowden Hall, Darlington, has secured a contract to the value of £350,000 for supplying and laying railway sidings at the new Park Gate Iron and Steel Company plant at Aldwarke and Roundwood, Rotherham. This is stated to be the largest single railway sidings contract placed with the company since its inception 121 years ago, and to be one of the largest contracts of its kind ever placed for railway sidings in this country.

ATLAS STEELS LTD., of Canada, has been awarded a contract, valued at several million dollars, to supply technical information and training services to Hindustan Steel Ltd. in connection with a special steel plant to be set up at Durgapur, India. The plant, which is being engineered by an Indian firm of consultants, is scheduled to be in operation by 1965. It will produce alloy, stainless and tool steels. Initial output will be about 80,000 tons a year, with provision for an ultimate capacity of 300,000 tons.

G.E.C. (ENGINEERING) LTD. has received instructions from the British General Electric Company Pty. Ltd., of Australia, to manufacture a double-drum, single-clutch, geared d.c. winder, for Oakdale State Coal Mine. The approximate value of the contract is £A180,000 and installation is scheduled to take place during the annual holiday period of Christmas, 1962. The winder will be used to raise 500 tons of coal an hour from a 1350ft deep mine shaft by balanced skips, each with a capacity of 8 tons of coal.

POWER-GAS CORPORATION LTD. has been awarded a contract by the North Thames Gas Board for a 60,000,000 cubic feet per day continuous reforming plant. The plant, due to go into operation at Southall in July, 1963, will use a hydrocarbon feedstock which will be supplied by pipeline from the Esso Refinery at Fawley, Hampshire. The plant will consist of four furnace units, each complete with prehydrogenation and shift conversion plant. The final specific gravity of the gas will be adjusted by carbon dioxide washing in a "vetrocoke" carbon dioxide removal plant.

STANDARD TELEPHONES AND CABLES LTD. has been awarded a contract for the supply of a transmitter for use by the G.P.O. in satellite communication experiments to be carried out next year in co-operation with the American authorities. The equipment will be installed in a room built into the 85ft diameter steerable aerial now being erected at a site on Goonhilly Down, in Cornwall. The transmitter will operate in the 2000 Mc/s communication band, and will deliver a frequency-modulated output of 10kW. Additional items to be supplied by the company include power equipment for the transmitter and a water-to-air heat exchanger unit. The present programme calls for the whole transmitter to be installed on site and fully operational by April, 1962. An active repeater communication satellite to be launched by the U.S.A. authorities will enable tests to be conducted on television transmission and two-way speech communication between Cornwall and the American ground station at Rumford, Maine.

Award

THE ROYAL SOCIETY has announced the award of the Sylvester Medal to Professor P. Hall, F.R.S., Sadleirian professor of pure mathematics in the University of Cambridge, for his distinguished researches in algebra, and of the Hughes Medal to Professor A. H. Cottrell, F.R.S., Goldsmiths' professor of metallurgy in the University of Cambridge, for his distinguished work on the physical properties of metals, particularly in relation to mechanical deformation and to the effects of irradiation.

Death

WE record with regret the death of Dr. Edwin Gregory, M.I.Chem.E., M.I.E.I., F.I.M., F.R.I.C., who died on November 7 at the age of sixty-seven. Dr. Gregory had been a director of Edgar Allen and Co. Ltd. for fifteen years and was chief metallurgist from 1944 until his retirement from executive duties in March, 1961.

CONTINENTAL AFFAIRS

by Our Continental Editor

4000 h.p. Diesel Hydraulic Locomotive

Following trials on the German Federal Railways and the Semmering line, six diesel-hydraulic locomotives of 4000 h.p. continuous rating were recently delivered to the U.S.A. by a German locomotive builder. They are claimed to be the largest diesel-hydraulic locomotives in service at the present time.

THE number of diesel locomotives of more than 200 h.p., commissioned or under construction, in the West is estimated to be 54,000 ; sufficient information about the numbers in the Soviet Union and Eastern Bloc States is not available. About 9000, or 17 per cent, are fitted with hydraulic transmissions. A few years ago, the firm Krauss-Maffei A.G., Munich-Allach, built the first six diesel-hydraulic locomotives of more than 2000 h.p., namely the well-known " V-200 " of the German Federal Railway. Since then this locomotive has been developed into standard designs with two-axle and three-axle bogies. Two hundred and fifty-two more engines, ranging from 2200 to 3000 h.p., have been supplied or are under construction. The latest stage is the recent delivery to the U.S.A. of what are claimed to be the most powerful diesel-hydraulic units to date, six locomotives with a continuous rating of 4000 h.p. These are destined for the mountainous lines of the Denver and Rio Grande Western and the Southern Pacific Railroad companies. For that reason they have been equipped with hydro-dynamic brakes in order to spare the brake shoes on the downhill runs.

Like all the larger diesel-hydraulic locomotives, the " ML 4000 " (Fig. 1), which has the axle arrangement C_0-C_0, has its drive system divided into two equal power units each of which acts by way of Cardan shafts on the three axles of the bogie next to it. As regards the superstructure, there is a driving cab at one end only, the other being formed by the truncated locomotive body. This " A-unit " design is typical in the United States for locomotives intended mainly for multiple traffic. It offers the advantage of a shorter overall length by enabling the two cooler plants to be installed asymmetrically in relation to the centre. A further circumstance helping to keep the engine short is that no heating boiler is required, as it is intended principally for goods haulage.

While the front of the locomotive corresponds to American design practice, the roof line differs from it, inasmuch as the roof of the engine compartment is lower than that of the cab. This gives some additional clearance in tunnels, with the result that the inlet temperature of the combustion and cooling air is lower ; moreover, the exhaust can be watched through small rearward-facing windows near the roof of the cab. As the engine had to be tested on this side of the Atlantic, limitations due to the loading gauge led to the upper part of the sides being sloped inwards, although as a matter of fact, the European loading gauge is slightly exceeded. In addition, the axle loads are in excess of European standards owing to the greater adhesion weight required, and the considerable amount of fuel to be carried. The general data of the locomotive are given in the table.

Power Plant and Transmission.—Two identical power units are fitted, each driving one of the bogies, and consisting of a Maybach " MD 870 " sixteen-cylinder vee-engine. The " MD 870 " is a four-stroke diesel with pressure charging and intercooling of the charging air, developing 2000 h.p. at 1585 r.p.m., at 20 deg. Cent. and 736mm Hg. Each engine rests on vibration-damping rails on the main frame.

Data of " ML 4000 " C_0-C_0 Diesel-Hydraulic Locomotive

Engine output at 200m above sea level, 20 deg. Cent. (U.I.C. conditions)	2 × 2000 h.p.
Gauge	4ft 8½in (1435mm)
Length over couplings	20,100mm
Height above rails	4729mm
Overall width	3275mm
Distance between bogie centres	11,676mm
Wheelbase of bogie axles	1750mm
Wheel diameter	101·6cm
Axle load	25 tonnes
Weight in working order, approx.	150 tonnes
Weight empty, approx.	132 tonnes
Maximum speed	112km.p.h.
Maximum radius of curves	76·3m
Fuel tank capacity	12,400 litres

The transmission, which is connected through an elastic coupling of the flywheel, comprises a Voith triple torque converter, model " L8-30 r U " with built-in reversing gear, and power take-off situated at the bottom on one side (Fig. 2). It is mounted on the main frame on two vibration-damping rails at the rear and two " Silentblocs " in front.

From the torque converter, the drive is taken through an intermediate gear resting on the bogie to three bevel-gear axle drives.

A starter-dynamo is geared, by way of an elastic coupling, to the drive shaft of each transmission. The combustion air for the engines is drawn in through plate oil-impregnated filters set behind openings in the side walls of the body. The exhaust gases leave through stacks in the roof by the shortest possible route.

Two large fuel tanks are arranged one behind the other under the main frame between the bogies. Electric pumps transfer the fuel to the injection pumps, provision being made for pre-heating.

The cooling water radiators form self-contained units, arranged in vee-formation aft of each engine. Air is drawn in through lateral louvres, passes through the radiators, and is exhausted upwards by fans, three to each engine. These fans are driven by oil motors powered by piston oil pumps which are driven by the main engines. By means of a thermostat-regulated by-pass, the cooling water temperature controls the oil pressure for driving the fans. The cooling water flows in a straight circuit through the cooler, engine jackets, and heat exchangers for the transmission oil and engine lubricating oil. A secondary circuit for cooling the charging air passes through a separate set of radiators cooled by the third fan which also serves a small section of the main circuit. Each power plant is provided with an oil-fired preheater for the cooling water.

In order to improve the cooling in tunnels in which the air has become heated by exhaust gases, each cooler has a set of downward-spraying nozzles arranged along its upper edge. From a tank at the rear wall of the engine room, water may be pumped electrically to the nozzles and a spray curtain laid in front of the entire cooling surface.

Frame.—The welded frame is built up principally of two longitudinal broad-flanged " I "-section girders connected by fabricated blocks under the diesel engines and above the bogies, while the end members are steel castings with pockets for the central couplers. It is designed to withstand without lasting deformation the normal service loads plus a buffer pressure of 454 tonnes (1,000,000 lb).

The frame rests on each bogie at two points situated in the transverse plane passing through the bogie centre and well outside the lines of the wheels. This is stated to result in an even load

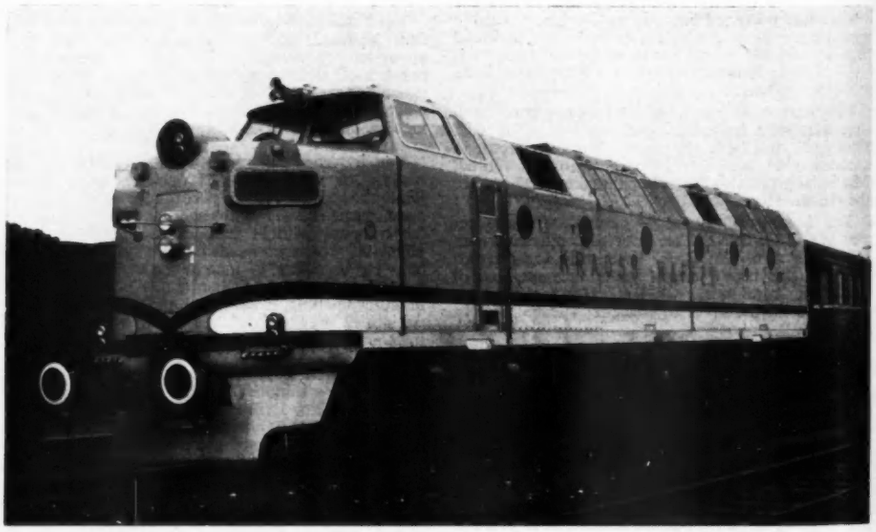


Fig. 1—4000 h.p. diesel-hydraulic locomotive with hydro-dynamic brake. For the purpose of the test run, during which the photograph was taken, the drawgear was modified ; normally a central coupler is used. Note swing link bogie suspension, underslung fuel tanks, single cab and reduced height of engine compartment

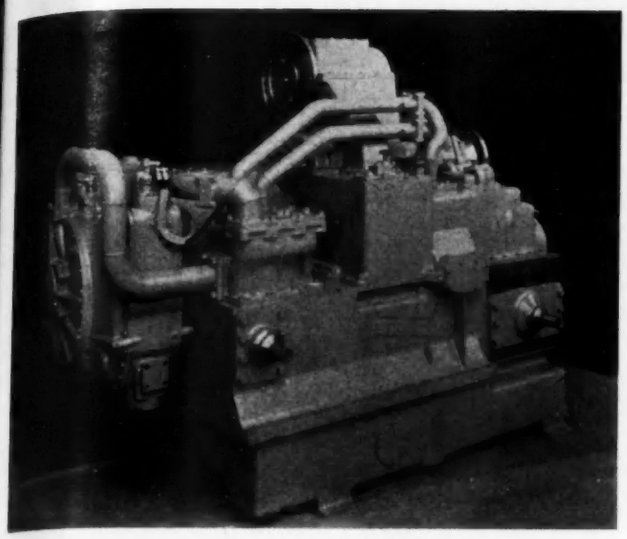


Fig. 2—Hydraulic transmission with hydro-dynamic brake on left. Input and output shafts are at the opposite end. At the top is the flange for the starter-dynamo

distribution and uniform riding quality in both directions of travel.

Bogies.—Of all-welded box design, the bogies (Fig. 3) make special provision for Cardan shaft drive; designed for improved riding qualities the/ are stated to be particularly economic on maintenance because of low wear. In the absence of a convenient space for a kingpin, the bogie is a kingpin-less design, a system of rubber-mounted links and bell crank levers being used to make it turn about a virtual centre. Pulling and braking forces are transmitted between the bogie and the main frame by manganese steel liners. An intermediate gearbox mounted on the bogie frame permits the use of short Cardan shafts between the output side of the hydraulic transmission and the axle drives.

Rigid swing-arms hinged to the bogie frame in rubber blocks support the wheelsets which are mounted in roller bearings. The rubber mountings help to maintain constant running conditions and also assist in absorbing lateral shocks.

At each end the main frame rests on two rubber bolsters which are supported on the bogies by means of a beam carried pendulum fashion on swing links and helical springs. These springs are mounted on parts of the bogie frame which laterally overhang the line of the wheels. When the bogie is swinging, the links take up the displacement by a change in their inclination, and thereby counteract the movement. Under normal conditions the spherical ends of the swing links do not touch the corresponding stops on the main frame which are fitted to provide a seating in case of failure of a helical spring.

Except for a few joints of the brake rods and the suspension, which require occasional lubrication, all other components, in particular the sealed axle drives and self-aligning roller bearings, do not require any attention over long periods.

Superstructure.—The superstructure consists of the hood and the two engine room sections which are firmly bolted to the frame, and the cab which rests on rubber cones ; the connections between the different sections are made by means of rubber profiles. All four main parts of the superstructure are completely self-contained fabricated units consisting of a framework of folded steel sections to which the outer walls are spot-welded. Sound-absorbing material is sprayed on to the inside of the engine room walls, while the cab is double-walled, the space between the outside walls and a perforated sheet metal lining being filled with an acoustic and thermal insulation of mineral wool. Openings are provided in the floor and roof for dismantling the cardan shaft between the forward engine and the hydraulic transmission, but for removing the transmission itself the whole of the front hood has to be taken off. Additional openings are provided for access to parts of the brake system and for dismantling the forward starter-dynamo. The two complete cooler plants including louvres, fans and stacks, are suspended in openings in the engine room sections and can be removed in one piece, removal of the rear cooler unit giving access for taking out the rear hydraulic transmission. Longitudinal gangways along both sides of the engine rooms may be entered by way of doors in the sides or from the cab which itself is fitted with side doors, while front and rear doors make it possible to pass from one locomotive to another. Daylight enters by thirteen round windows in the side walls and rear walls. At the rear end is a w.c. supplied with water from a sub-section of the spray tank. The engine room is ventilated by two fans drawing in air through sheet metal ducting from the front intake louvres. After passing through plate filters, this air is blown towards the finned intercoolers of the brake air compressors.

Cab.—Set back by the length of the front hood and raised as high as the loading gauge permits, the cab offers good visibility to the front and sides. The two large front windows are provided with pneumatic windscreen wipers, defrosters, and four manually adjustable sun visors. Above the front windows are openable ventilation flaps. On the platform are three upholstered adjustable seats side by side, the driver's being on the right with all controls arranged within reach, i.e. on a central table, the control and brake pressure gauges, warning lamps, and switches, to the left of the table, the master controller for the drive and hydraulic brake, the reverser and its control lamps, and the recording speedometer. To the right of the table is the brake column with the engineman's brake valves and the levers for sanding and bellringing. In the centre of the cab under the front windows is an air-conditioning plant which, through louvres in the front hood, draws in air which may be heated by cooling water from either power plant. To the left of the air-conditioning plant is a cooler for drinking water.

Driving Controls.—All driving controls are pneumatically operated, the compressed air being supplied by two 225 cubic feet per minute, 1000 r.p.m. compressors. These are belt-driven by the diesel engines and arranged in the central engine room section which also contains the two main air reservoirs with a combined capacity of 800 litres. Most of the air is required for the compressed air brakes, and beside them and the control system, air is also supplied to such accessories as sanders, a three-horn typhoon, windscreen wipers, &c.

The controller has seventeen running notches, the first initiating the partial filling of the torque converter for slow and sensitive movements of the locomotive by itself. At the second notch the starting converters are filled up to normal with engines idling, while at the third to seventeenth running notch the various stages from minimum to full load are successively switched on.

Also pneumatically operated is the reverse gear and the hydro-dynamic brake, and, indirectly, the deadman's control, overload protection (interlock between engine load and brake cylinder pressure). Of other interlocking and safety devices, some are operated electrically, and some electro-pneumatically. Particular mention may be made of the wheel slip protection comprising an electric transmitter and a magnetic valve.

Controls and safety devices have been arranged for multiple tractions, and the necessary piping and hose and cable couplings are provided.

Hydraulic Transmission.—The model " L 830 r U " hydraulic transmission made by J. M. Voith G.m.b.H., Heidenheim (Brenz) is shown in Fig. 4. It incorporates three converter stages based on the Föttinger principle, i.e. each comprises essentially, in a single cavity of the housing, an impeller which absorbs the input and transforms it into kinetic energy of the oil filling, a turbine runner which converts this energy into mechanical output, and a stationary number (guide wheel) which takes up the reaction moment.

The common impeller shaft is driven by the input shaft through a step-up gear which also forms part of the gear train of the starter-dynamo. By varying the gear ratio the transmission can easily be matched to different diesel engines. At the end opposite to the input shaft is the power take-off for the fan pumps. A

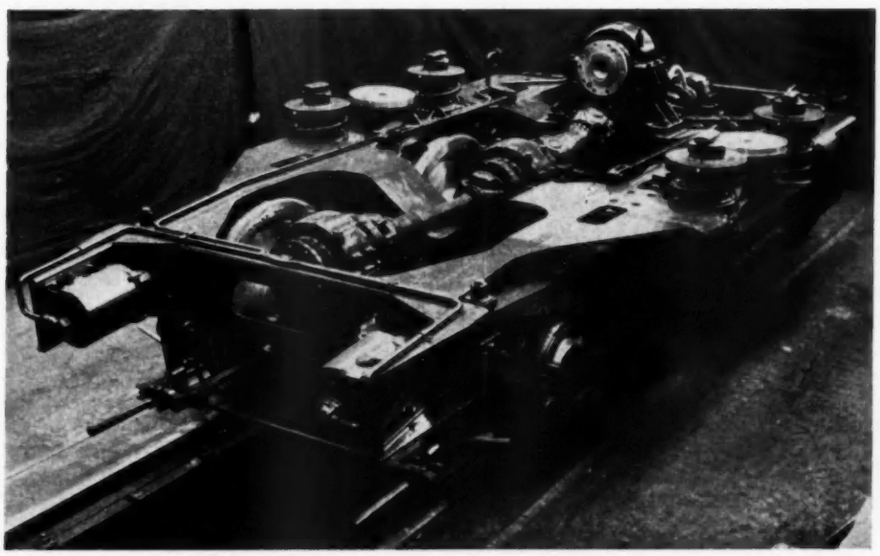
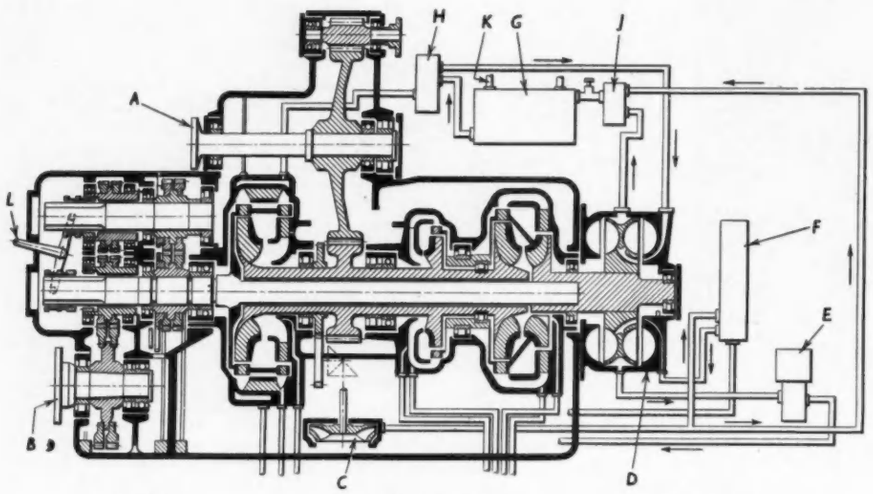


Fig. 3—Bogie with intermediate gearbox and three axle gearboxes. Details of the suspension are clearly seen. The main frame rests by means of rubber bolsters on the two discs visible above the centre axle

CONTINENTAL AFFAIRS *(Continued)*



A—Input.
B—Output.
I, II, III—Converter stages.
C—Filling pump.
D—Hydrodynamic brake.
E—Filling limiting valve
F—8-position filling regulator
G—Heat exchanger.
H—Braking valve.
J—Duplex non-return valve.
K—Cooling water.
L—Forward/reverse gear.

Fig. 4—Diagrammatic arrangement of transmission with hydrodynamic brake

geared power take-off from the impeller shaft drives the filling pump. Gears are also interposed between the turbine runners and the output shaft, in particular the forward/reverse gear (operated only at standstill). All gears are permanently in mesh.

The three converter stages are each assigned a well-defined speed range of the locomotive. By automatically energising the hydraulic circuits in turn one obtains optimum efficiency for the prevailing track speed and engine operating conditions. Converter I is used for starting, whereas converters II and III are used in running.

The main control of the transmission, namely that directing the delivery of the filling pump to the various hydraulic circuits, is itself actuated by the engine output (position of fuel controller) and the track speed. This is done through a small spring-loaded centrifugal governor which by means of pressure oil positions the control piston valve of the main system.

The engine fuel lever is linked with the transmission control in such a way that as the lever is moved from the idling position to the first notch, the transmission as a whole is switched on. This single-lever control enables the train driver to give his full attention to the road. It can be readily adapted to multiple or remote control.

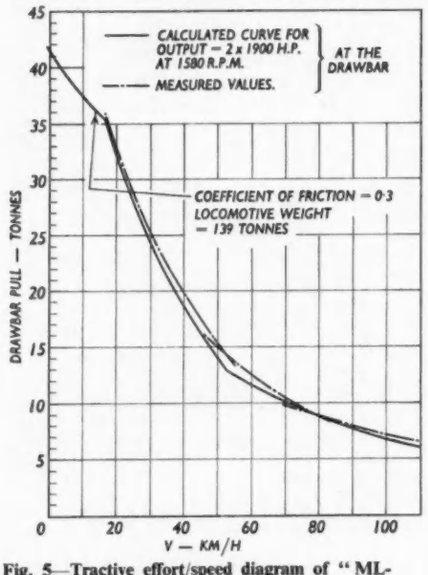


Fig. 5—Tractive effort/speed diagram of "ML-4000" diesel-hydraulic locomotive

The hydrodynamic brake is fitted to the end of the impeller shaft. Designed on the principle of the Froude brake it has a double-sided rotor and stator which are energised and de-energised smoothly by filling and emptying its hydraulic circuit. Oil is supplied from the sump of the hydraulic transmission by the converter filling pump. For braking, the oil circulates in a closed circuit, through the brake and a heat exchanger belonging to the transmission. The heat developed by the brake is transferred to the engine and transmission cooling water circuit, which is feasible since during braking the engine itself develops practically no power. Apart from the obvious economy of this arrangement, there is the advantage that the diesel engine is kept warm during long downhill runs in cold weather.

Energy absorption by the brake is adjusted by varying the oil filling. This is done by an eight-position regulating valve. Since heat dissipation and torque impose an upper limit on the amount of energy which the brake can absorb, it is protected from overload by a separate valve which automatically limits the degree of filling (and at the same time acts as a relief valve, should the oil pressure exceed a preset maximum). From the limiting and regulating valves the oil returns to the sump of the transmission. The brake is stated to be designed for efficiency over a wide range of speeds during level runs, as well as limiting the train speed on long downhill runs.

Tests.—Measurements were carried out in co-operation with the German Federal Railway's experimental test department for internal combustion engines at Munich. Trials which extended over ten days took place earlier this year on the line between Münster and Emden, an almost level run with four curves which enables constant conditions to be realised. As braking load, two "Class 45" heavy goods steam engines were employed for the speed range 0 to 80 km.p.h., while two "Class 184" express engines were used for the range 80 to 110 km.p.h. The train consisted of the one "ML 4000" diesel-hydraulic locomotive, one dynamometer car, one standard carriage for the staff, one equipment car, and the two braking locomotives.

On the run from Münster to Emden the tractive effort of the "ML 4000" was measured, the steam engines serving as braking locomotives. On the return journey these roles were reversed and the "ML 4000" tested for its braking capacity. Tractive effort was measured by the change in ohmic resistance of strain gauges attached to the draw spindle, and registered by an electronic compensating recorder. An a.c. tacho-generator, on one of the axles of the dynamometer car, measured the running speed which was also recorded. A piston fuel counter served to measure the consumption of the two diesel engines, its readings being electrically transmitted to relay counters in the dynamometer car. Pressures in the main and secondary circuits of the cooler fans were measured by means of pressure cells and registered on a twelve-point recorder. Two similar recorders were employed for the diesel engine speeds, and air, water, and oil temperatures. Figs. 5 and 6

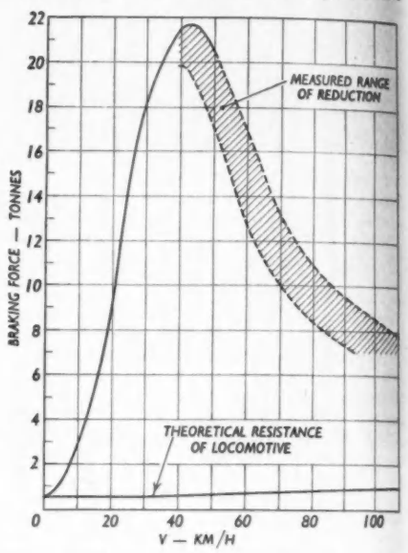


Fig. 6—Brake power of hydrodynamic brake at drawbar. Cooling capacity 1400 h.p. per engine at ambient temperature of 50 deg. Cent.

display the relationships between running speed and pull at the drawbar, engine speed, and braking effort. During the trials the starting tractive effort was measured. This was interrupted at the fifteenth engine notch when the tractive effort was 48 tonnes, indicating for the 139-tonne locomotive, a coefficient of friction of 0·345. This test lasted a total of 2 min. 34 secs., and no thermal overstrains are reported to have occurred.

In addition to these test runs over a level route, trials were conducted on the Semmering Line in Austria in order to evaluate the performance under conditions resembling those on the American lines where the engines will be employed.

150th Anniversary of Fried. Krupp

On November 20, 1811, Friedrich Krupp (1787–1826) founded his factory at Essen "for the manufacture of English crucible steel and all its secondary products." The family had been connected since the middle of the eighteenth century with the local iron and coal industry. Although some experience in steelmaking was gained, the favourable position created for prospective steel producers by Napoleon's Continental blockade of 1806 collapsed with the end of the Napoleonic era. At his death Fried. Krupp left to his son, then aged fourteen, a small works with a staff of four, and debts of 10,000 thalers. It was under Alfred Krupp (1812–87) that the spectacular rise of the company took place. A gifted technical innovator, although without formal training, with a shrewd gift for commerce, Alfred Krupp developed at first the production of steel rolls and coining dies (compound roll construction, 1831; design for a four-high mill, 1836; rolls for cutlery manufacture, 1842). At the Hyde Park Exhibition of 1851, Krupp showed a steel ingot weighing 2150 kg. In 1853 followed the

Fig. 1—Interior of locomotive works, Essen

seamless steel tyre for railway wheels, which later, in 1875, became the motif of the firm's trade mark ; by 1914, some 2,750,000 such tyres had been supplied. Other important landmarks are the introduction on the Continent of the Bessemer process (1862), and the first Siemens-Martin plant in Germany (1869), the 500-ton steam hammer "Fritz" (1881), and the first testing laboratory (1862). An important, and subsequently notorious, development began with the manufacture of rifle barrels in 1847, which was later extended to the production of other classes of armaments, notably artillery and armour plate, resulting in such technically advanced designs as the World War I Paris gun "Dicke Bertha," and—in the last war—the 80cm Sebastopol gun "Dora," with its 7·1 ton projectile and 35km range.

Alfred Krupp was much ahead of his contemporaries in the social policies which he patriarchically pursued and which formed the pattern of much of the social legislation in the new German Empire. His slogan that " the object of work should be the general welfare" was put into practice by the introduction of health insurance and a burial fund (1836), old age pensions (1858), and the building of large numbers of works-owned flats, later of hospitals, a nurses' home, a library, and other facilities. At Alfred Krupp's death the firm employed over 20,000 people, and had an annual turnover of 42·2 million marks. His son, Friedrich Alfred Krupp (1854–1902) added the Grusonwerk engineering works, Magdeburg, and the Germania shipyards at Kiel. A development of the highest technical significance was the collaboration with Rudolf Diesel and M.A.N. in the construction of the first successful diesel engine (1897). The number of employees rose to 43,000 in 1902.

In the field of steel production many important advances were made such as experiments with alloy steels, with additions of nickel, tungsten, and chromium, the building in the years 1896–1905 of an important Siemens-Martin and Thomas steel plant at Rheinhausen, the installation in the early 1890's of the first 5000-ton hydraulic forging press, the introduction of electro steel (1907), and the invention of chromium-nickel stainless steel (1912). Other metallurgical advances were the development of the " Wipla " stainless steels for use in dentistry, of " Widia " sintered hard metal (1926), of the application of welding to high-tensile austenitic steels, and of nitriding. In collaboration with I.G. Farben, a steel capable of resisting high pressure hydrogen was developed for use in the Haber-Bosch synthesis of ammonia.

With the collapse of armament manufacture in 1918, the works were changed over to a wide range of civilian production, including such items as locomotives, excavators, railway rolling stock, lorries, and even motor scooters.

After the death of Friedrich Alfred Krupp, his eldest daughter Bertha Krupp (1886–1957) inherited the firm, which in 1903 was transformed into a joint stock company, the chairman of the board of directors from 1909 to 1943 being Bertha Krupp's husband, Gustav Krupp von Bohlen und Halbach (1870–1950). In 1943 the joint stock company was changed again into a private enterprise with Alfred Krupp von Bohlen und Halbach (born 1907) as its owner.

In the last four decades the history of the firm has been marked by several crises traceable in a large measure to the association—until the end of World War II—with the armaments industry, and to political and economic upheavals.

Among technical events, with which this survey is chiefly concerned, mention may be made of the world's first 15,000-ton press for forging blocks up to 300 tons, a steam turbine locomotive and the beginning of diesel locomotive production (1924–25), the Krupp-Renn steelmaking process for low-iron acid ores (1929), the first series-produced air-cooled diesel for vehicles (1934), the first valve-controlled two-stroke diesel for vehicles (1936), and during the war, a Bêche double-acting die-forging hammer of 80,000 kgm capacity, and the introduction of a heat resisting titanium-nickel alloy (" Tinidur ") for jet engines.

Under an Allied order of 1953, the firm was placed under an obligation to sell its steel and coal holdings, but this has not yet been carried into effect. Annual production of crude steel is 4,000,000 tons, while coal output amounts to 5·8 million tons. Engineering production—aspects of which are illustrated in Figs. 1 and 2—comprises at the present time over 3500 items, ranging from the planning and erection of complete factories and plants, bridges, large excavators, locomotives, cranes, and other machinery, to church bells, artificial teeth, and watch springs. The pressure sphere of the bathyscaph which in January, 1960, descended to a depth of 11,000m in the Pacific was also produced by Krupp's. Recently a self-contained mobile water purification plant was put on the market which has a continuous rating of 8 cubic meters per hour which can also be adapted to decontaminate radio-active water supplies, and makes use of collapsible synthetic fibre storage tanks. Other products include a large dome-shaped tent for building or storage purposes, supported without the use of a framework, entirely by a slight internal excess air pressure. Now under construction at Jülich is a high temperature nuclear reactor developed jointly with Brown, Boveri & Cie which uses spherical fuel elements of uranium carbide encased in graphite. The chief aim is to increase the cycle efficiency by operating the core at up to 2000 deg. Cent.

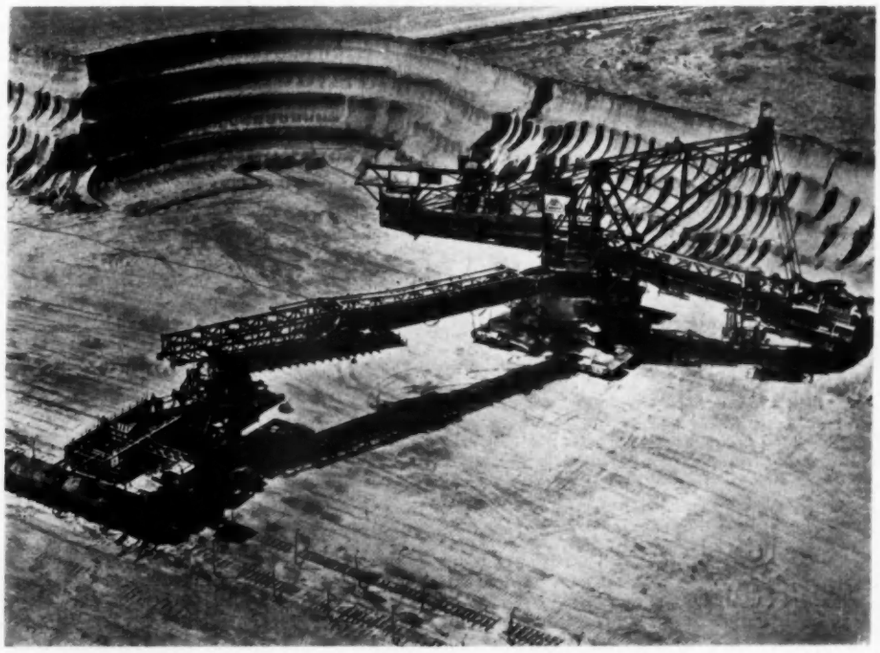


Fig. 2—Bucket-wheel excavator with conveyor bridge and crawler-mounted loading unit working in the Rhineland lignite mining area

THE AMERICAN SCENE

By Our American Editor

Operation of Nuclear Power Plants of the U.S. Atomic Energy Commission

No. II—(*Continued from page* 844, *Nov.* 17, 1961)

The Division of Reactor Development of the U.S. Atomic Energy Commission has released certain operating characteristics of its various power reactor plants installed in the United States. The information relates both to nuclear power stations and to experimental plants, and includes pressurised water reactors, boiling water reactors, organic cooled reactors and sodium-cooled reactors. Of particular interest are the data on everyday plant operating experience and on radiation intensities encountered during operating and maintenance periods.

Experimental Boiling Water Reactor

THE Experimental Boiling Water Reactor (E.B.W.R.) (Figs. 7 and 8) is situated at the Argonne National Laboratory. The reactor went critical on December 1, 1956 and reached its rated power of 20MW(t) on December 29, 1956. The E.B.W.R. is a direct cycle, natural circulation, boiling water reactor. At full power, the reactor has produced 60,000 lb per hour of steam at 600 lb per square inch gauge for generating 5MW(e). The E.B.W.R. is primarily an experimental plant intended to provide as much information as possible for use in designing large central station units. Because of the experimental programme carried on with the plant, the reactor is frequently shut down for preparation and carrying out of planned experiments. This type of operation is reflected in the relatively low thermal and electrical energy accumulated since the start of power operation. Representative operating experience of E.B.W.R. is summarised in Fig. 9.

The majority of operating problems that have been experienced were on the so-called conventional equipment in the plant. There have been no significant problems that were nuclear in origin except for the "sticking" of the control rods experienced during the early operation of the E.B.W.R. This problem was associated with accumulation of crud in the rod seal housing at the bottom of the reactor vessel. It has been largely corrected by substituting bushings made of softer material. This crud accumulation also results in a high activity level in the immediate vicinity of the control rod thimbles. Activity levels of the order of 70 r per hour have been reported.

A failure of a turbine blade presented no servicing problems. The slightly radioactive (about 2 mr per hour) machine was repaired in a conventional manner. A leak in a tube of the main condenser was also repaired with no difficulty from radioactivity. The radiation levels with the E.B.W.R. operating at 20MW(t) are shown in Table V. The radioactive liquid waste produced at the E.B.W.R. amounts to about 30,000 gallons per year with a specific activity of about 5×10^{-5} microcuries per millilitre. This waste is the excess water bled off following hydrostatic tests which are performed on the E.B.W.R. system each time the reactor vessel is opened. The wastes are discharged through the Argonne National Laboratory waste disposal system.

TABLE V—*Radiation Intensities at the E.B.W.R.*

	Activity in mr per hour
Operating at 20MW(t) :	
Top of reactor	One
Steam dryer	150
Turbine inlet	50
Turbine casing	4
Air ejector after-cooler	400
Condenser hot well	40
Stack exhaust duct	3
Sub-reactor room	10
Feedwater filters	10
Ion exchanger pre-filter (inside shielding)	500/1000
Ion exchanger (inside shielding)	500/1000
Ion exchanger after-filter (not shielded)	500/1000
Start-up heater	400
Twenty-four hours after shutdown :	
Steam dryer	0·5
Main steam piping	0·2
Turbine trip valve	0·2
Condenser :	
Steam dome	0·2
Hot well	2·0
While servicing equipment :	
Feedwater filters	5
Control rod bushings	2
Top of ion exchanger resin bed	1000
Pre-filter	500
After-filter	500
Inside turbine (downstream of nozzle block)	0·1 to 0·2

The solid wastes at the E.B.W.R. amount to about 100 cubic feet per year containing about 100 millicuries of activity per cubic foot. The spent ion-exchange resin beds account for about 10 to 20 per cent of this volume, with the balance ranging from wiping rags to assorted debris. The radiation levels of the spent resin beds averaged about 10 r per hour at contact.

The active gaseous effluents from the E.B.W.R. are predominantly xenon–138 and krypton–88, which are discharged to the atmosphere. The normal daily discharge rates at 20MW(t) operation are 0·2 to 0·4 curie of xenon–138 and 0·005 to 0·01 curie of krypton–88. During a test period when an oxide test fuel element was deliberately defected, the discharge of these isotopes rose to 1·0 and 0·08 curie per day, respectively.

Although the E.B.W.R. with its first core was rated at 20MW(t), it has been operated stably at a power level of 60MW(t). On July 3, 1959, the reactor was shut down for modifications to provide additional heat removal capacity for increasing the E.B.W.R. rating to 100MW(t).

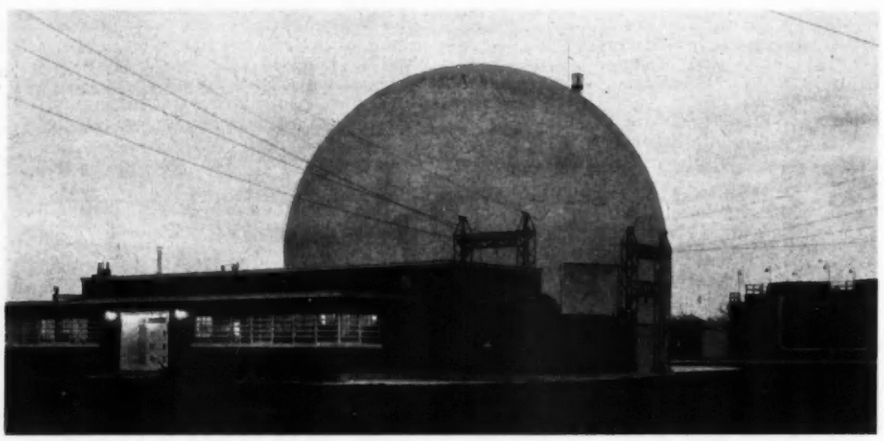


Fig. 7—20MW(t) Experimental Boiling Water Reactor at the Argonne National Laboratory in Illinois

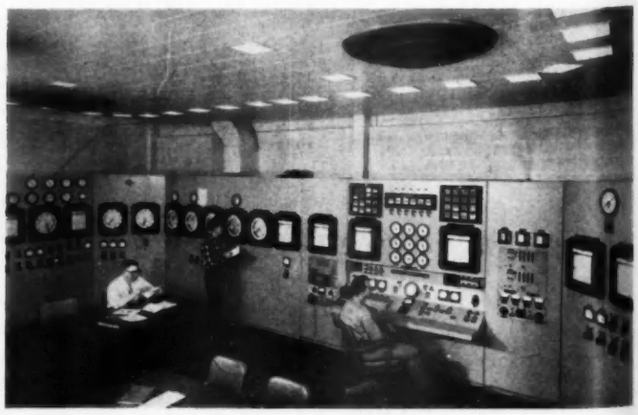
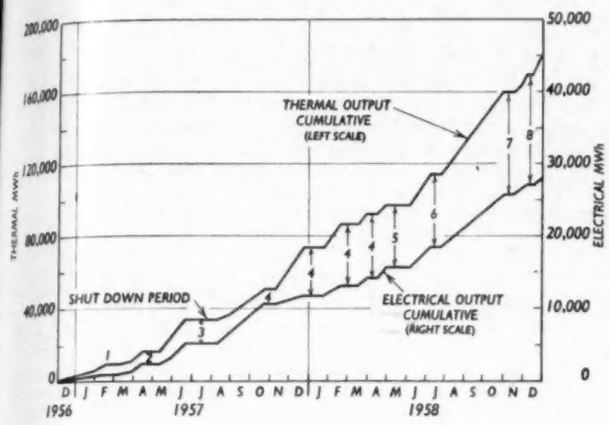


Fig. 8—Control room of the Experimental Boiling Water Reactor at Argonne



SHUT DOWN PERIODS

1. Operator training.
2. General maintenance.
3. Modification for reactor stability tests.
4. Reactor stability tests.
5. Turbine blade failure.
6. Insertion of defective fuel sample for tests.
7. Removal of defective fuel sample.
8. Insertion of defective fuel sample for tests.

Fig. 9—Operating experience of the Experimental Boiling Water Reactor

Stationary Low-Power Reactor No. 1

The SL-1,* formerly known as the A.L.P.R., is a 3MW(t) natural circulation, direct cycle boiling water reactor designed to generate 300KW(e) gross power and 400KW(t) space heat. The reactor (Fig. 10) is situated at the National Reactor Testing Station in Idaho and achieved criticality on August 11, 1958 and power operation on October 23, 1958. The plant has been operated for performance evaluation and operator training of military personnel. The operation and maintenance experience of SL-1 indicates that boiling water reactors can be operated for continuous and steady generation of power. The malfunctions and resulting unscheduled downtime are summarised in Table VI for the SL-1 plant during the period from February 5, 1959 to September 30, 1960. The 921 hours downtime due to malfunctions amounts to about 6·4 per cent of the total time. This could be reduced by about two or three percentage points by performing maintenance on a three-shift basis and on weekends. The plant operated a total of 9109 hours during this period, or about 63 per cent of the time, and produced 747MWD(t). During the remaining 37 per cent of the time, except for downtime due to malfunctions, the plant was down to accommodate the research and development and testing programme carried on at the site.

Table VI—*SL-1 Malfunction Summary*

February, 1959–September, 1960

No. of Malfunctions	Description	Plant downtime hours
7	Electrical equipment	67
1	Fan motor	61
6	Station auxiliary circuit breaker	6
8	Control system	54
2	Tube in H.V. supply	11
1	Tube in high level indicator	3
4	Insulation breakdown in inst. cable	39
1	Failure of reactor water level indicator	1
17	Mechanical equipment	749
2	Turbine governor	7
3	Valves	33
1	Reactor vessel gasket	356
3	Control rod drives	12
3	Ejectors	78
1	Water purification pump	25
1	Punctured screen in mixed bed resin column	163
3	Steam leaks in primary piping	75
9	Operator error	51
1	Turbine throttle valve not opened fully	3
1	Wrong fuse pulled	1
1	Shorting of circuit	1
1	Loss of coolant	1
2	Incorrect adjustment of turbo-generator control linkage	2
1	Incorrect test instrument installation	1
1	Operator error	3
1	Accidental addition of resin to primary system	39
41	Total	921

* As reported previously in THE ENGINEER, on January 3, 1961, while the SL-1 was shut down for maintenance, an explosive accident occurred which killed three men. This review gives only information about the operation of the reactor prior to January 3, 1961.

All liquid waste resulting from the SL-1 operations is collected in retention tanks for sampling, measurement, and subsequent discharge to a leaching bed. The low-level waste results from seal leakage, equipment and plant decontamination during maintenance work, spillage, water used to transfer spent ion exchange resins, and laboratory drains. During February, 1959 to September, 1960, a total of about 41,000 gallons of liquid waste was produced with a total activity of about 124,000 microcuries or about 8×10^{-4} microcuries per millilitre. This is an average of about 70 gallons per day under all conditions, and for periods of normal operation the average is about 30 gallons per day.

The solid wastes produced at the plant are in the form of contaminated paper, rags, filters, and spent ion-exchange resins. During the previously mentioned period, a total of 484 cubic feet of solid waste containing approximately 7000 microcuries and weighing 1700 lb was shipped to the N.R.T.S. burial ground.

The radioactivity released to the environment from the air ejector venting system averaged about 0·5 curie per MWD(t), except during September 1960, when 6·2 curies per MWD(t) were released. The increase in September was due to operating the reactor with an instrumented fuel assembly which had thermocouples inserted into holes drilled into the edge cladding and fuel region. The off-gas activity is due to xenon-138, 135 and 133, and krypton-88 and 85.

Table VII—*SL-1 Radiation Levels During Full Power Operations*

	mr per hour
General operating floor	3– 5
Middle turbine control panel	5– 7
Purification Panel	17– 31
Floor over purification vault	65–150
Floor over purification vault, after addition of lead	20– 35
Feedwater pump	1– 5
Main steam line near reactor	20– 30
Main steam line near turbine	5– 10
Turbine casing	4– 11
Condenser	45– —
Hotwell	3– 8
Simulated heat load heat exchanger trap	28–300

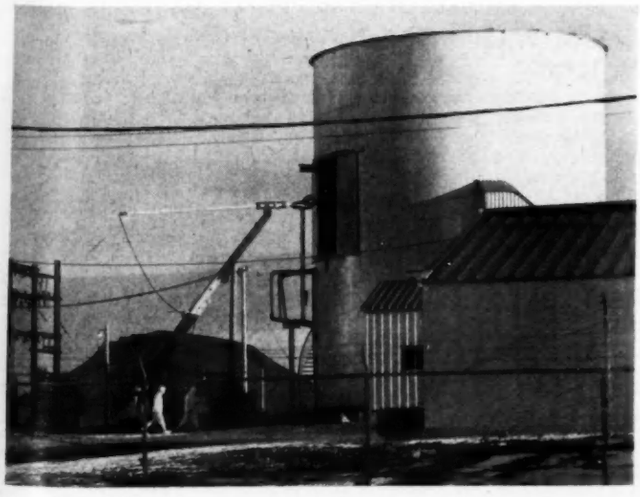


Fig. 10—3MW(t) Stationary Low-power Reactor No. 1 in Idaho, with mobile crane used to obtain photographs of the vessel interior after the recent accident

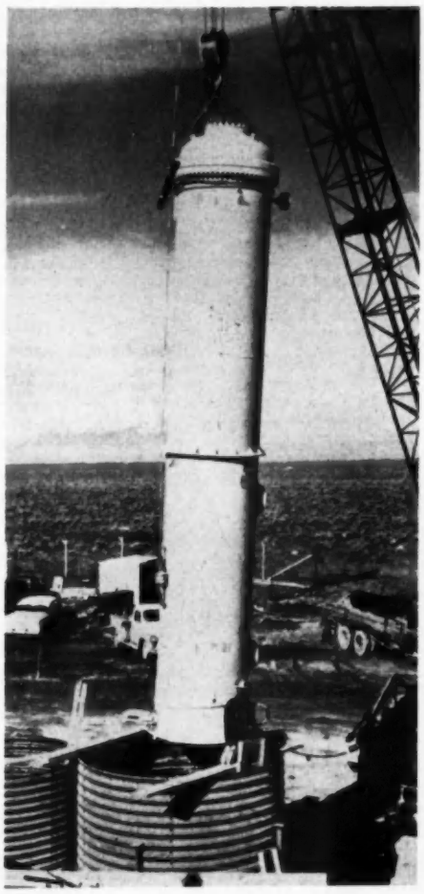


Fig. 11—Erection of the reactor core tank of the Organic Moderated Reactor Experiment in Idaho

ORGANIC COOLED REACTORS

The only operating organic cooled reactor in the United States is the Organic Moderated Reactor Experiment (O.M.R.E.) which was designed and constructed at a minimum cost to test and demonstrate the economic and technical feasibility of the organic concept. The reactor (Fig. 11) is not a prototype of a power plant but rather a full-scale irradiation plant, and, as such the information and experience obtained from the facility is more useful to the reactor designer than to the power station operator.

Full power operation was begun in February, 1958. During the first two years of O.M.R.E. operation, the plant was used primarily to study

THE AMERICAN SCENE *(Continued)*

organic coolants. Tests were conducted at high boiler concentrations of approximately 12, 30 and 40 per cent and at bulk coolant temperatures of 600 and 750 deg. Fah. to determine the radiolytic and thermal decomposition rates and heat transfer properties of the coolant. The reactor was then shut down for system cleanup and removal of inorganic particulate matter which had accumulated in the system, as well as the installation of the second core. At the same time, modifications to the reactor vessel head assembly were made to permit a greater number of experimental instrumentation leads to pass from the core vessel. The second core was installed

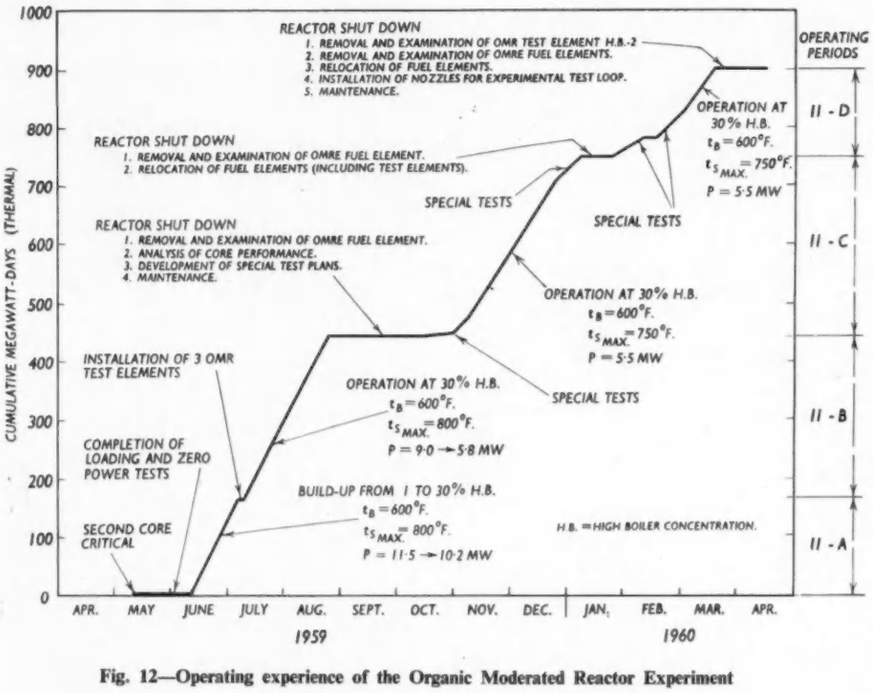


Fig. 12—Operating experience of the Organic Moderated Reactor Experiment

in May, 1959 and operations continued. During the second core operation, scheduled interruptions were made to examine various fuel and test elements and to investigate the extent of material buildup on the heat transfer surfaces.

In March, 1960, the reactor was shut down for the removal of the second core fuel elements.

Prior to the shutdown, one fuel element showed evidence of high outlet temperature readings from the hottest channel. Upon examination, several of the coolant channels of this element were found partially plugged by particulate material bridging across at various points in the channels. The basic cause of film formation on fuel element surfaces is believed to be due to the presence of inorganic particulate matter in the coolant. The inorganic contamination is due principally to rust which forms the reactor system is opened to the air and moisture. Also, film formation is believed to be accelerated by electrostatic effects resulting from the relatively high current of beta electrons from the thin-plate, fully-enriched elements of the basic O.M.R.E. loading. Also, near the end of first core life, a test element failed because particulate matter had plugged the entrance of the coolant channels and reduced the coolant flow enough to cause the aluminium cladding and some of the uranium to melt.

During the shutdown at the end of second core operation, preparations were made for the installation of a coolant particulate removal system, modifications to the auxiliary systems, and the installation of the third core. The operating history of the O.M.R.E. with the second core is summarised in Fig. 12.

The entire system, with the exception of the flanges, and pump seals have presented no problems. For piping connections, bolted flanges used in conjunction with soft-iron gaskets have proved to be leakproof when properly installed. The average decomposition rate of organic coolant during power operation of the reactor at 30 per cent high boiler concentration amounted to 53 lb per MWD. This is equivalent to 28·3 lb per MWh of energy absorbed in the organic coolant based on a radiation energy absorption rate of 7·8 per cent of the total reactor power.

(To be concluded)

Special Meeting of the Iron and Steel Institute in America

By invitation of the Metallurgical Society of the American Institute of Mining, Metallurgical and Petroleum Engineers, a special meeting of the Iron and Steel Institute was held in the United States of America and Canada, from October 17 to November 8. Some 280 members of the Institute and guests took part in the visit, which started in New York, moved on to Canada via Niagara Falls and returned to travel through seven states, reaching as far west as Chicago before beginning the homeward journey.

Though most of the visitors were British, the party included representatives of industry and the academic field from Austria, Belgium, France, Germany, Holland, India, Japan, Sweden and Switzerland. In addition, a number of the Americans and Canadians who acted as hosts, were members of the Institute.

The areas visited were substantially the same as those which featured in the programme for the last visit paid by the Institute, in 1904 (a visit arranged for 1939 was cancelled because of the outbreak of war). But if the areas were the same the plants were very different, for some of the companies visited during 1961 had only just come into existence in 1904, and some had, at the earlier date, yet to be formed. On the recent visit the Institute members had the privilege of seeing not only America's largest integrated steelworks (the Sparrows Point, Maryland, plant of the Bethlehem Steel Company) and the newest (Fairless Works, Fairless Hills, Pennsylvania, of the United States Steel Corporation), but also upwards of a dozen others, of varying sizes and types. In short, a very good cross-section of the American and Canadian steel industries was provided, covering blast furnace operation, steel making (open hearth, L.D. and electric), primary and finish-rolling and tinplate and galvanised sheet manufacture. Certain steel products, such as wire and nails were also seen in course of manufacture.

Nor was the all-important subject of research neglected. Two large steel company research centres (Republic Steel at Independence, Ohio, and United States Steel at Monroeville, Pennsylvania), and three other company laboratories dealing with allied subjects (Union Carbide Metals Company, Niagara Falls, N.Y.; Linde Company, Tonawanda, N.Y.; and Gulf Research and Development Company, Harmaville, Pennsylvania) were visited.

Throughout the tour the visitors found that not only had comprehensive arrangements been made for their reception and for showing them the plant, but that visits by persons with specialised interests to parts of the plant not scheduled for visiting were welcomed. In short, the American steel industry's reputation for having nothing to hide, for welcoming detailed technical questions and sparing no trouble to provide the answers, was fully vindicated. Everywhere it was a case of ask and be told.

It was, perhaps, this attitude of helpfulness which left the most lasting impression on the visitors. The sheer scale of the American iron and steel industry was, of course, itself impressive. So, too, was the fact that the industry was fully alive to the problems which it faces now and will face in the future, from competition, from raw material shortages (not so acute in America as in some parts of Europe, for example, but there, nevertheless) and from the ever-present need to keep costs down and to reduce them whenever possible. The industry's awareness of all these problems was reflected in its massive research programmes, in its constant study of production processes, and in its efforts to promote the sale of steel in old and new markets. But overall was the feeling that the United States steel industry regards steel as international and is only too ready to share its knowledge and experience.

Data Reduction and Correlation

Two established British firms, West Instrument Ltd. and Mervyn Instruments, have been acquired by Gulton Industries (Great Britain) Ltd., a subsidiary of Gulton Industries Incorporated. It is anticipated that these firms will operate in conjunction with particularly the Ortholog Division of Gulton Industries Inc., which is active in the reduction, correlation and transmission of data yielded by instruments, its efforts being directed to those fields where progress is limited by the noisiness of observations. Three techniques in particular have been explored by the Ortholog Division: (1) data reduction at the originating end of the link, thereby reducing the bandwidth needed for monitoring "stationary" parameters by 10^4; (2) automatic synthesis of correlations between two signals, e.g. stimuli to and responses from a human operator, the noise within a submarine and that picked up by a hydrophone; (3) improvement of signal-to-noise ratio by application of optimum combining techniques to a plurality of measurements of one parameter.

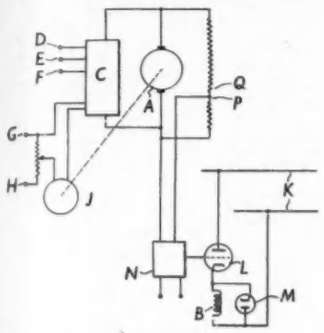
BRITISH PATENT SPECIFICATIONS

The dates printed are those of application and publication on completion. Copies of specifications may be obtained at the Patent Office Sales Branch, Southampton Buildings, Chancery Lane, W.C.2, 3s. 6d. each

ELECTRICAL ENGINEERING

879,928. February 11, 1957.—SPEED CONTROL OF ELECTRIC MOTORS, Associated Electrical Industries, Ltd., 33, Grosvenor Place, London, S.W.1. (*Inventor : Leon Babad.*)

This invention relates to the control of direct current motors which have their armature connected to an alternating current supply source through thyratrons, and aims at an improved circuit arrangement which increases the range of speed control, the whole speed range being covered by a single operating member, such as a control lever or knob. In the embodiment illustrated diagrammatically, the motor to be controlled comprises an armature *A* and a field winding *B*, the armature being supplied through an electronic control unit, particularly one of the "Emotrol" kind. This unit *C* is connected through terminals *D*, *E*, *F*, to a three-phase alternating



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current supply. A potentiometer having terminals *G*, *H* for connection across a constant voltage source, for providing a reference voltage to be compared with a feedback voltage derived from a tachogenerator *J*, mechanically coupled to the armature *A*, serves to control the armature voltage for regulating the speed of the motor. Field winding *B* is supplied from an alternating current source *K* through a triode valve *L*, a diode *M* being connected across the said winding. The grid of the valve *L* is connected to a phase shifting device *N* having terminals for connection to a bias voltage opposing a primary signal derived from the armature voltage so that the current flow through the valve is reduced after a predetermined armature voltage has been attained. The primary signal input to the phase shifting network *N* is taken from an intermediate point *P* of a potential divider *Q*, connected across the armature *A*, so that a low voltage signal is derived from the armature voltage, for the phase shifting device, this signal being for a predetermined range of armature voltage less than the bias voltage which opposes it. As soon as with rising armature voltage the primary (input) signal to the phase shifting device equals the bias voltage, any further rise in armature voltage influences the phase shifting device, so that the phase of the voltage applied to the grid of the grid-controlled rectifier is altered with respect to the anode voltage in a manner to increase its effective impedance, and thus to reduce the current in the field winding.—*October* 11, 1960.

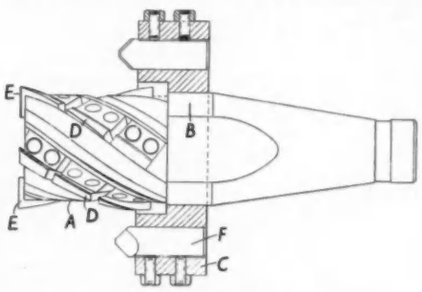
879,511. June 27, 1958.—CONTROL MEANS FOR ELECTRIC SWITCHES, The General Electric Company Ltd., Magnet House, Kingsway, London, W.C.2. (*Inventor : Stanley William Clives*).

This invention relates to control means for electric switches such as electric circuit-breakers, particularly circuit-breakers used in feeder circuits and motor control units. With most circuit-breakers used in association with electric motors, it is impossible to start a motor direct to line without causing the breaker to trip through the action of the over-current release trip, usually provided, and to overcome this it has previously been necessary to add to the breaker a separate unit to restrain the action of the breaker when the motor is starting direct to line. According to the present invention, a single depressable and rotatable button is associated with the breaker operating mechanism. The button is of generally cylindrical form and provided with grooves transverse to its axis. The button may be depressed to trip the switch and then rotated through 90 deg. to lock the switch off. This is effected by a locking gate engaging with a groove on the button, and being secured if desired by a padlock. If the button is turned the opposite way, it brings into action a restraining spring which prevents the trip mechanism from operating on normal motor starting current, although in fault conditions the restraining effect of the spring is overcome so that the breaker trips. A further condition allows the button to be locked so that it can neither be depressed nor turned, this being an optional position which is used while the breaker is closed, but earthed.—*October* 11, 1961.

MACHINE TOOLS

879,870. October 28, 1957.—MILLING CUTTERS, Purefoy Engineering Company Ltd., Upper Tilt Works, Cobham, Surrey. (*Inventors : John Bagwell-Purefoy and William Sydney Cooper.*)

The invention provides a milling cutter suitable for cutting on at least three angularly disposed faces simultaneously. As will be seen from the drawing, the cutter body has a tapered rear portion and a cylindrical front portion *A* with an intermediate portion *B* having opposed flats to engage in a positionally adjustable collar cutter *C*. The cylindrical portion of the body has helical grooves for receiving tips *D* clamped in position to provide one series of cutting edges. The cutting tips in each groove are spaced longitudinally and the foremost tip *E* extends to provide a cutting edge at right angles and radially of the cylindrical portion. The body is detachable from the collar and this facilitates grinding of the cutting tips. Further to facilitate grinding of the tips, additional helical grooves are formed in the cylindrical portion to act as reference grooves for a grinder finger. The collar *C* is recessed on its front face to accommodate the rearmost cutting tips so



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that, if required, it can be moved up to the edge of a surface being machined by the helical edges of the cutters. In the example shown, provision is made for cutting a further surface parallel to that machined by the ends of the tips. For this purpose the collar is provided with spaced apertures, in each of which there is secured a tipped cutting tool *F*. With the tool described three surfaces can be machined simultaneously as for example the inner surfaces of an L-section member.—*October* 11, 1961.

GAS PURIFICATION

879,112. February 14, 1958.—PURIFICATION OF GASES, Humphreys and Glasgow Ltd., Humglas House, Carlisle Place, London, S.W.1. (*Inventor: Wilfred Hartley.*)

This invention is concerned with gas purification processes in which hydrogen sulphide is scrubbed from gases by an aqueous alkaline suspension of oxide, hydrated oxide or basic carbonate of iron, the suspension being regenerated by oxidation for reuse in the process. As is known in such a process the hydrogen sulphide is converted first to soluble alkali sulphides which then react with the iron compound to form iron sulphides. The sulphided liquor from the gas washers is then oxidised by aeration which results in regeneration of the iron compound suspension and liberation of sulphur. It is important that reaction between the soluble alkali sulphides and the iron compound should be rapid and extensive. It has now been found that in such a process the reactivity of the iron compound in fresh or regenerated suspension is considerably improved by the presence in the suspension of alkali phosphate. According to the present invention an improvement is effected in a gas purification process by the incorporation in solution in the iron compound suspension of an alkali salt of phosphoric acid ; if desired two or more alkali salts of phosphoric acid may be used together. The alkali salt of phosphoric acid used is conveniently tri-sodium orthophosphate. In the preparation of a fresh concentrated suspension satisfactory results are obtained when the tri-sodium orthophosphate is present in an amount 2 per cent to 25 per cent by weight of the iron as ferric oxide. Preferably from 5 per cent to 10 per cent of tri-sodium orthophosphate is used.—*October* 4, 1961.

ELECTRONICS

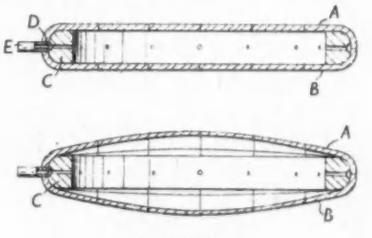
879,660. May 1, 1958.—INFORMATION STORAGE APPARATUS, National Research Development Corporation, 1, Tilney Street, London, W.1. (*Inventors : George Richard Hoffman and Donald Henry Smith.*)

This invention proposes the use of the fluorescence of electroluminescent materials as a means of storing binary information. Fluorescence is caused by subjecting the material to changes of potential, for example to an alternating potential which may be at high frequency. It is proposed to use as a light source the fluorescence of an electroluminescent material and to represent bits of binary information by the presence or absence of such fluorescence. In addition it is proposed to control the energisation of the electroluminescent material by use of a photoconductive material constituting a path of controllable resistivity for the energising voltage. Thus, the electroluminescent material provides a light source which can be rapidly switched on and off by the switching on and off of an alternating energising voltage, while the photoconductive control element provides a readily controllable but relatively slow-acting switch for determining whether the electroluminescent element is to represent a "0" or a "1" in the binary notation. However, although a photoconductive element is slow in reacting to incident light to attain a low resistance state, this time being of the order of 100 milleseconds, once having been put into such a state the conduction time of a signal applied to such an element is effectively negligible, or at most of the same order as the reaction time of an electroluminescent element when energised. Moreover, both the electroluminescent and the photoconductive elements lend themselves to the construction of compact matrices suitable for storage of large numbers of bits of binary information.—*October* 11, 1961.

METAL FORMING

879,713. October 30, 1957.—METHOD OF FORMING A DOMED MEMBER FROM SHEET OR PLATE, John Thompson (Wolverhampton) Ltd., Ettingshall Engineering Works, Wolverhampton. (*Inventors: Richard Godfrey Greenwood and Gerald Keith Mantle.*)

The invention relates to a method of forming a domed member suitable for use as an end of a pressure vessel from sheet or plate metal. The drawings show the stages in the formation of two similar domed members. Two similar circular dish shaped parts *A* and *B* having peripheral rims are each fabricated from a single plate built up from a number of steel panels welded together. A circular, cast-iron, ring-die *C*, with a peripheral groove *D* through which there are number of radial bores, is made a close fit within the rim of the part *B*. The second part *A* is placed on part *B* and their rims are welded together.



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The parts thus constitute a hollow body which is fluid tight and has an annular side wall of the same diameter as the required domed members. Water under pressure is pumped through an inlet tube *E* to the interior of the hollow body to inflate it into spheroidal shape as shown in the lower view until the curvature of the end walls is equal to that required in the domed members. The hollow body is then cut in two along the centre line of the annular wall, the peripheral groove in the die facilitating this operation, to provide two similar domed members. The ring-die may be used repeatedly.—*October* 11, 1961.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS

To-day, Nov. 24.—COVENTRY AND DISTRICT BRANCH: Conservative Rooms, 16, Queens Road, Coventry, "Industrial Motor Control Gear," B. Eardell, 8 p.m. ★ OXFORD AND DISTRICTS BRANCH: Technical College, Walton Road, Aylesbury, "Power Factor Correction," T. A. Williams, and film, "Capacitors Pay Dividends," 7.30 p.m. ★ STOKE AND CREWE BRANCH: Grand Hotel, Hanley, "Temperature Control," L. Clarke, 7.30 p.m.

Mon., Nov. 27.—NORTH WEST LONDON BRANCH: Compass Hotel, Watford, "Modern Electric Lifts," 8.15 p.m.

Tues., Nov. 28.—ALDERSHOT AND DISTRICT BRANCH: Basingstoke Technical College, Worting Road, Basingstoke, "The National Inspection Council," T. Howell, 7.30 p.m. ★ LEICESTER BRANCH: Shakespeare Inn, Brownstone, Ladies' Evening, 7.30 p.m.

Fri., Dec. 1.—LIVERPOOL AND DISTRICT BRANCH: Industrial Development Centre, M.A.N.W.E.B., Paradise Street, Liverpool, 1, "Mechanics of the Human Body," R. G. Harrison, 7.30 p.m.

BRITISH INSTITUTION OF RADIO ENGINEERS

Tues., Nov. 28.—SOUTHERN SECTION: Technical College, Farnborough, "Data Acquisition Systems," K. L. Smith, 7 p.m.

Wed., Nov. 29.—ELECTRO-ACOUSTICS GROUP: London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1, "An Experimental Assessment of Loudspeaker Performance," R. Yorke, 6 p.m.

Fri., Dec. 1.—SOUTH MIDLANDS SECTION: North Gloucestershire Technical College, Cheltenham, "Electronic Telephone Exchanges," J. F. Hesketh, 7 p.m.

CEMENT AND CONCRETE ASSOCIATION

Mon., Nov. 27.—College of Further Education, High Wycombe, Bucks., "Essentials of Good Concreting," E. E. H. Bate, 7.15 p.m.

Wed., Nov. 29.—Technical College, Woodhouse Lane, Bishop Auckland, Film Show, "Building Problems and Techniques," 7.15 p.m.

Thurs., Nov. 30.—Y.M.C.A., Connaught Hall, Blackett Street, Newcastle upon Tyne, "Good Concrete from Local Aggregates," R. Cameron, 7.15 p.m.

COMBUSTION ENGINEERING ASSOCIATION

Tues., Nov. 28.—NORTH WESTERN REGION: Engineers' Club, Albert Square, Manchester, "Liquid Petroleum Gas—the Present and Future Position in U.K.," R. B. Cutts, 2.30 p.m.

ILLUMINATING ENGINEERING SOCIETY

Mon., Nov. 27.—BIRMINGHAM CENTRE: Chamber of Commerce, 75, Harborne Road Edgbaston, Birmingham, 15, "Lighting of Large Office Buildings," J. H. D. Madin, 6.30 p.m.

INSTITUTE OF BRITISH FOUNDRYMEN

Wed., Nov. 29.—SOUTHAMPTON SECTION: Technical College, St. Mary's Street, Southampton, "Origin, Detection and Elimination of Gases in Cast Metals," D. V. Atterton, 7.30 p.m.

INSTITUTE OF MARINE ENGINEERS

Tues., Nov. 28.—DEVON AND CORNWALL SECTION: Royal Naval Engineering College, Maradon, Plymouth, "The Automatic Control of Naval Boilers," J. P. N. Brown and W. J. R. Thomas, 7.15 p.m. ★ JOINT PANEL ON NUCLEAR MARINE PROPULSION: Memorial Building, 76, Mark Lane, London, E.C.3, "High Temperature Gas Cooled Reactors for Marine Propulsion," J. E. Richards, 5.30 p.m.

Mon., Dec. 4.—STUDENT LECTURE: Memorial Building, 76, Mark Lane, London, E.C.3, "Marine Diesel Engines," E. W. Cranston, 6.30 p.m.

INSTITUTE OF METALS

Wed., Nov. 29.—SOUTHAMPTON METALLURGICAL SOCIETY: Technical College, Southampton, "Organic Detecting and Elimination of Gases in Cast Metals," D. V. Atterton, 7.15 p.m.

Tues., Dec. 5.—LEEDS METALLURGICAL SOCIETY: University Staff House, University Road, Leeds, "Dislocations," J. Nutting, 6.30 p.m.

INSTITUTE OF PETROLEUM

Wed., Dec. 6.—61, New Cavendish Street, London, W.1, "Charge Relaxation in Hydrocarbon Liquids Flowing through Conducting and Non-Conducting Pipes," J. A. Carruthers and K. J. Marsh, and "The Estimation of Electrostatic Potentials, Fields, and Energies in a Rectangular Metal Tank Containing Charged Fuel," K. J. Wigley and J. A. Carruthers, 5.30 p.m.

INSTITUTE OF PHYSICS AND THE PHYSICAL SOCIETY

Wed., Nov. 29.—NORTH EASTERN BRANCH: King's College, Newcastle upon Tyne, "The Origin of Life in Solar Systems," J. D. Bernal, 6 p.m. ★ YORKSHIRE BRANCH: The University, Leeds, "Traffic Management in London." G. Charlesworth, 5 p.m.

INSTITUTION OF CHEMICAL ENGINEERS

To-day, Nov. 24.—SCOTTISH BRANCH: Lea Park Tea Rooms, Falkirk, "Absorption on the Surface of a Sphere," G. Stewart, 7.30 p.m.

Thurs., Nov. 30.—LONDON CENTRE: King's College, Strand, London, W.C.2, "Process Control," A. H. Isaac, 6.45 p.m. ★ EDINBURGH CENTRE: Room 342, The Old College, The University, Edinburgh, "Chemical Processes Associated with the Atomic Energy Industry," 7.30 p.m.

INSTITUTION OF CIVIL ENGINEERS

Tues., Nov. 28.—Great George Street, Westminster, London, S.W.1, "The Development of Modern Dry Dock Equipment," John Read, 5.30 p.m.

Thurs., Nov. 30.—Great George Street, Westminster, London, S.W.1, Discussion on "The Relative Merits of Rigid and Flexible Construction for Quays and Jetties," introduced by D. H. Little, 5.30 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

To-day, Nov. 24.—SOUTH MIDLAND CENTRE EDUCATION DISCUSSION CIRCLE: College of Technology, Gosta Green, Birmingham, "A Materials Course for Electrical Engineers," G. T. Wright, 6.15 p.m.

Mon., Nov. 27.—NORTH-EASTERN CENTRE: Neville Hall, Westgate Road, Newcastle upon Tyne, "The Place of Formal Study in the Post-Graduate Training of an Electrical Engineer," N. N. Hancock and P. L. Taylor, 6.15 p.m. ★ SOUTH MIDLAND ELECTRONICS AND MEASUREMENT GROUP: James Watt Memorial Institute, Birmingham, "Electronics in the Electric Supply Industry," J. S. Forrest, 6 p.m. ★ NORTH STAFFORDSHIRE SUB-CENTRE: Mechanics Institute, Crewe, "Electric Traction," J. A. Broughall, 7 p.m. ★ WESTERN UTILISATION GROUP: South Wales Institute of Engineers, Cardiff, "Silicone Electrical Insulation," J. H. Davis, 6 p.m.

Tues., Nov. 28.—EAST MIDLAND CENTRE: The University, Nottingham, Third Hunter Memorial Lecture, "The Application of Electronics to the Electricity Supply Industry," J. S. Forrest, 6.30 p.m. ★ NORTH WESTERN SUPPLY GROUP: Engineers' Club, Manchester, "General and Topological Features of Some Hydro and Thermal Schemes," J. R. Mortlock, 6.15 p.m. ★ SOUTH EAST SCOTLAND SUB-CENTRE: Carlton Hotel, North Bridge, Edinburgh, "An Impression of Moscow," M. G. Say, 7 p.m. ★ SOUTHERN CENTRE: Technical College, Farnborough, "Brushless Variable-Speed Induction Motors Using Phase-Shift Control," F. C. Williams, E. R. Laithwaite, K. F. Eastham and W. Farrer, 6.15 p.m.

Wed., Nov. 29.—ELECTRONICS AND COMMUNICATIONS SECTION: Savoy Place, London, W.C.2, "Recent Developments in Semiconductor Devices and their Applications," E. Wolfendale, 5.30 p.m. ★ LONDON GRADUATE AND STUDENT SECTION: Medway College of Technology, Maidstone Road, Chatham, Kent, "Some Aspects of the Control and Guidance of Guided Weapons," J. A. Miller, 7 p.m. ★ LONDON GRADUATE AND STUDENT SECTION: Visit to London Transport Executive, Railway Repair Works, Acton, 2 p.m. ★ EAST MIDLAND CENTRE: George Hotel, Kettering, "The Kariba Dam Project—Electrical Installations," C. J. Dickinson, 7.30 p.m. ★ CAMBRIDGE ELECTRONICS AND MEASUREMENT GROUP: Cavendish Laboratory, Free School Lane, Cambridge, Electronics and Communications Section Chairman's Address, "Global Communication," R. J. Halsey, 8 p.m. ★ SOUTH WEST SCOTLAND SUB-CENTRE: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, C.2, "The Banana-Tube Display System—A New Approach to the Display of Colour-Television Pictures," P. Schagen, 6 p.m. ★ RUGBY SUB-CENTRE: College of Engineering Technology, Rugby, "An Oscillating Synchronous Linear Machine," E. R. Laithwaite, and R. S. Mamak, and "The Application of Linear Induction Motors to Conveyors," E. R. Laithwaite, D. Tipping and D. E. Hesmondhalgh, 6.30 p.m. ★ SOUTHERN CENTRE: C.E.G.B. Offices, High Street, Portsmouth, "Technical and Economic Aspects of the Supply of Reactive Power in England and Wales," W. Casson and H. J. Sheppard, 6.30 p.m.

Thurs. to Fri., Nov. 30 *to Dec.* 1.—MEASUREMENT AND CONTROL SECTION: Savoy Place, London, W.C.2, Meeting in conjunction with the British Nuclear Energy Conference, Symposium on "Nuclear Electronics," 5.30 p.m.

Fri., Dec. 1.—SOUTHERN CENTRE: South Dorset Technical College, Weymouth, "The Banana-Tube Display System—A New Approach to the Display of Colour-Television Pictures," P. Schagen, 6.30 p.m.

Sat., Dec. 2.—LONDON GRADUATE AND STUDENT SECTION: Visit to A. E. Reed and Co. Ltd., Aylesford Paper Mills, 10 a.m.

Mon., Dec. 4.—ELECTRONICS AND COMMUNICATIONS SECTION: Savoy Place, London, W.C.2, Discussion on "Backward Waves in Waveguides," opened by P. J. B. Clarricoats, R. A. Waldron and G. H. B. Thompson, 5.30 p.m. ★ MERSEY AND NORTH WALES CENTRE: Royal Institution, Liverpool, "Simulation of Intelligence," D. M. MacKay, 6.30 p.m. ★ NORTH EASTERN MEASUREMENT AND ELECTRONICS GROUP: Rutherford College of Technology, Northumberland Road, Newcastle upon Tyne, "Planning and Installation of the Sound Broadcasting Headquarters for the B.B.C.'s Overseas and European Services," F. Axon and O. H. Barron, 6.15 p.m. ★ SCOTTISH ELECTRONICS AND MEASUREMENT GROUP: Royal College of Science and Technology, Glasgow, "Precision Measurement," G. H. Rayner and A. Felton, 6 p.m. ★ SOUTH MIDLAND CENTRE: College of Technology, Birmingham, "The Banana-Tube Display System—A New Approach to the Display of Colour-Television Pictures," P. Schagen, 6.30 p.m.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND

To-day, Nov. 24.—Technical College, Dundee, Joint meeting with Dundee Institute of Engineers, "The Atom in the Future," W. R. Wootton, 7.30 p.m.

INSTITUTION OF HEATING AND VENTILATING ENGINEERS

Tues., Nov. 28.—Lecture Theatre, Junior Institution of Engineers, Pepys House, 14, Rochester Row, London, S.W.1, Informal Debate, "This House Considers that Domestic Heating Installations Should be Carried Out by Qualified Heating Engineers and not by Other Professions or Trades," proposed by K. W. Dale, opposed by R. G. Sayers, 6.30 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

Sat., Nov. 25.—WESTERN GRADUATES' SECTION: Visit to the Swindon Works, British Railways, Western Region, 10 a.m.

Mon., Nov. 27.—EDUCATION AND TRAINING GROUP: 1, Birdcage Walk, Westminster, London, S.W.1, Discussion on "The Effectiveness of Postgraduate Courses," opened by W. A. Tuplin, 6 p.m. ★ MIDLAND GRADUATES' SECTION: College of Engineering Technology, Rugby, Films, 7 p.m. ★ NORTH EASTERN GRADUATES' SECTION: Rutherford College of Technology, Northumberland Road, Newcastle upon Tyne, "Reactor Fuel Element Design," M. O. Engel, 6.30 p.m.

Tues., Nov. 28.—AUTOMOBILE DIVISION: 1, Birdcage Walk, Westminster, London, S.W.1, Symposium on "Agricultural Tractors," 2.30 p.m. ★ MIDLAND BRANCH: College of Engineering Technology, Rugby, "Cost Reduction in Heavy Engineering," J. E. Chadbund, 6.30 p.m. ★ BIRMINGHAM A.D. CENTRE: James Watt Institute, Great Charles Street, Birmingham, "The Skidding Behaviour of Motor Vehicles," G. Jones, 6.30 p.m. ★ WESTERN A.D. CENTRE: Royal Hotel, Bristol, "Research Into Brake Usage in Passenger Cars," A. E. Livesey, A. F. Prestidge and D. F. Woor, 7 p.m. ★ EASTERN GRADUATES' SECTION: Queen's Engineering Works, Bedford, "The Field of Work Study," C. Dudley, 7.30 p.m. ★ SCOTTISH GRADUATES' SECTION: Visit to India Tyre and Rubber Company Ltd., Inchinnan, Renfrew, 7 p.m.

Wed., Nov. 29.—SOUTHERN BRANCH: Technical College, King's Road, Reading, Repetition of the Thomas Hawksley Lecture, "Controlled Fusion Reactions," P. M. S. Blackett, to be read by M. G. Haines, 7.30 p.m. ★ EASTERN GRADUATES' SECTION: Visit to C.A.V. Ltd., Cornard Road, Sudbury, 7.30 p.m. ★ EAST MIDLANDS GRADUATES' SECTION: College of Technology, Chesterfield, "High Pressure Water Tests on Pelton Nozzles," P. Sullivan, 7.15 p.m. ★ WESTERN GRADUATES' SECTION: Large Lecture Theatre, The University, Bristol, "People in Industry," G. F. Pitts, 7.30 p.m.

Wed. and Thurs., Nov. 29 *and* 30.—HYDRAULIC PLANT AND MACHINERY GROUP: 1, Birdcage Walk, Westminster, London, S.W.1, Conference on "Oil Hydraulic Power Transmission and Control," Wed., 10.45 a.m., Thurs., 10.30 a.m.

Mon., Dec. 4.—APPLIED MECHANICS, THEORY OF MATERIALS OF CONSTRUCTION GROUP: 1, Birdcage Walk, Westminster, London, S.W.1, Discussion on "Can Plastic Components be Designed Rationally?" 6 p.m. ★ NORTH EASTERN BRANCH: Neville Hall, Westgate Road, Newcastle upon Tyne, Repetition of the James Clayton Lecture, "The Bearing of Psychology and Medicine on Engineering," Sir Frederic Bartlett, 6 p.m. ★ NORTH WESTERN GRADUATES' SECTION: Literary and Philosophical Society, 36, George Street, Manchester, 1, Technical Film Show, 7 p.m.

INSTITUTION OF PLANT ENGINEERS

Mon., Nov. 27.—WEST AND EAST YORKSHIRE BRANCH: Houldsworth School of Applied Science, The University, Leeds, "Basic Electronics in Industry and Commerce," R. H. Garner, 7.30 p.m.

Tues., Nov. 28.—SOUTH WALES BRANCH: Electricity Showrooms, 62, Kingsway, Swansea, "Design for Maintenance," R. N. Dale, 7 p.m.

Fri., Dec. 1.—WEST AND EAST YORKSHIRE BRANCH: Guildford Hotel, Headrow, Leeds, Films, 7.30 p.m.

INSTITUTION OF PRODUCTION ENGINEERS

To-day, Nov. 24.—NORTH MIDLANDS REGION: Louis Room, St. James's Restaurant, St. James's Street, Derby, "Training Foremen," D. B. Beynon, 7 p.m.

Thurs., Nov. 30.—NORTH MIDLANDS REGION: Ruston Club, Lincoln, "Numerical Controlled Machine Tools," R. C. Brewer, 7.30 p.m.

Sat., Dec. 2.—LEEDS GRADUATE SECTION: Visit to Lawrence Wilson and Sons Ltd., Silver Cross, Guiseely, Yorks., 10 a.m.

Mon., Dec. 4.—EAST AND WEST RIDINGS REGION: Lecture Theatre, Engineering Tower, Technical College, Huddersfield, "Work Study," F. T. Mountford, 7.30 p.m.

INSTITUTION OF STRUCTURAL ENGINEERS

Tues., Nov. 28.—NORTHERN COUNTIES BRANCH: Technical College, Sunderland, "Reinforced Concrete Bridges," L. Dobson, 6.30 p.m. ★ EDINBURGH SECTION: Heriot-Watt College, Edinburgh, Joint Meeting with the Edinburgh and East of Scotland Association of the Institution of Civil Engineers, "Piling," W. G. N. Geddes, 6 p.m.

Wed., Nov. 29.—YORKSHIRE BRANCH: Royal Victoria Hotel, Sheffield, "Air Conditioning and Services for Tall Buildings," J. R. Kell, 6.30 p.m.

JUNIOR INSTITUTION OF ENGINEERS

To-day, Nov. 24.—Pepys House, 14, Rochester Row, Westminster, London, S.W.1, Annual General Meeting, 7 p.m.

Fri., Dec. 1.—Pepys House, 14, Rochester Row, Westminster, London, S.W.1, Films, "Handling Loose Materials," and "Mechanical Handling in Iron Production," 7 p.m.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS

To-day, Nov. 24.—Mining Institute, Newcastle upon Tyne, "An Evolution in Ship Control," H. E. H. Pain, 6.15 p.m.

PLASTICS INSTITUTE

To-day, Nov. 24.—MIDLANDS SECTION, REINFORCED PLASTICS GROUP: James Watt Memorial Institute, Great Charles Street, Birmingham, 3, "Developments in Curing Systems for Polyester Resins," J. W. Cywinski, 7 p.m.

Fri., Dec. 1.—NORTH WESTERN SECTION: Textile Institute, 10, Blackfriars Street, Manchester, 3, "Plastics in Batteries," R. G. Robinson and R. L. Walker, 6.45 p.m.

REINFORCED CONCRETE ASSOCIATION

Mon., Dec. 4.—NORTH WESTERN BRANCH: College of Technology, Sackville Street, Manchester, "Report on a Visit to Italy," G. R. Adams and J. B. Westall, 6.45 p.m.

ROYAL INSTITUTION OF CHARTERED SURVEYORS

Sat., Dec. 2.—MINING SURVEYORS GENERAL MEETING: College of Advanced Technology, Cardiff, "Magnetism, Climate and Coal," D. E. T. Bidgood, 9.45 a.m.

Mon., Dec. 4.—ORDINARY GENERAL MEETING: 12, Great George Street, Westminster, London, S.W.1, "Post-War Developments: The Location of Major Projects in England and Wales," E. C. Willatts, 5.45 p.m.

ROYAL INSTITUTION OF GREAT BRITAIN

To-day, Nov. 24.—21, Albemarle Street, London, W.1, "Seeing Atomic Defects in Metals," P. B. Hirsch, 9 p.m.

Fri., Dec. 1.—21, Albemarle Street, London, W.1, "The Science of Nature Conservation," E. B. Worthington, 9 p.m.

ROYAL INSTITUTION OF NAVAL ARCHITECTS

Tues., Nov. 28.—Institute of Marine Engineers, 76, Mark Lane, London, E.C.3, "High Temperature Gas Cooled Reactors for Marine Propulsion," J. E. Richards, 5.30 p.m.

ROYAL SOCIETY

Thurs., Nov. 30.—Burlington House, Piccadilly, London, W.1, Anniversary Meeting, 2.30 p.m.

SOCIETY OF ENVIRONMENTAL ENGINEERS

Wed., Nov. 29.—Imperial College, Mechanical Engineering Department, Exhibition Road, London, S.W.7, "The Response of Dynamic Systems to Shock Excitation," B. H. Venning, 6 p.m.

SOCIETY OF INSTRUMENT TECHNOLOGY

Tues., Nov. 28.—Manson House, 26, Portland Place, London, W.1, "Automatic Plant Analysis by Electrochemical Methods," R. F. Rodger, 6.30 p.m.

SOUTH LONDON PRODUCTIVITY ASSOCIATION

Tues., Dec. 5.—Council Chamber, Federation of British Industries, 21, Tothill Street, London, W.1, Afternoon Conference on "The Utilisation of the Blind in Industry," 2 p.m.

Advanced Engineering Courses

Structural Analysis by Influence Coefficients. BATTERSEA COLLEGE OF TECHNOLOGY, Department of Civil Engineering, London, S.W.11. Course of eleven lectures to be held on Monday evenings commencing January 8, 1962, from 6.45 p.m. to 9 p.m., covering the analysis of elastic structures using both flexibility and stiffness influence coefficients. The major portion of the work will be developed through the use of matrices which will be fully explained. The connection between the two methods will be shown. Practical methods of computing indeterminate structures, including the use of electronic computers, will be discussed. Fee £1.

Highway Bridge Design. BATTERSEA COLLEGE OF TECHNOLOGY, Department of Civil Engineering, London, S.W.11. Course of ten lectures to be held on Tuesday evenings commencing January 9, 1962, from 6.45 p.m. to 9 p.m. The course will cover the analysis of slab, box beam and tee-beam structures by the distribution coefficient method, with particular reference to design for the revised Ministry of Transport loading and cases of abnormal loading. Fee £1.

Structural Design in Timber. BATTERSEA COLLEGE OF TECHNOLOGY, Department of Civil Engineering, London, S.W.11. Eleven lectures to be held on Friday evenings commencing January 12, 1962, from 6.45 p.m. to 9 p.m. The course will cover the factors affecting strength; grading rules and working stresses; design of beams, columns, joints; glued laminated construction; truss construction; plywood; stressed skin panels; shell construction, with application of modern structural analysis techniques. Fee £1.

Problems of Radioactivity at Water and Sewage Works. DEPARTMENT OF MUNICIPAL ENGINEERING, Manchester College of Science and Technology. The course, which will be held on Thursday and Friday, January 11 and 12, 1962, has been designed as an introduction to the subject of radioactivity for water and sewage engineers and chemists and for others in public health who wish to become familiar with the principles of radiological protection. In conjunction with the course there will be an exhibition of nucleonic instruments currently available for work in this field. Seven lectures will be given during the two days and films will be shown each evening. Fee £7.